# Network Centric Operations Conceptual Framework

# Version 1.0

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# Network Centric Operations Conceptual Framework Version 1.0

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# 1.0 Introduction and Background

## 1.1 Overview of Transformation

Transformation is the roadmap that will lead the U.S. to "…a future force that is defined less by size and more by mobility and swiftness, one that is easier to deploy and sustain, one that relies more heavily on stealth, precision weaponry and information technologies."[1]

The need for transformation of the military is driven by the changing strategic environment (9-11 and the War on Terrorism) that the U.S. faces. Transformation is necessary because:[2]

- U.S. military superiority cannot be assumed in the future. As Information Age technologies proliferate, U.S. dominance will increasingly be challenged in novel ways.
- Growing asymmetric threats require new ways of thinking about conflict that require creative approaches
- Force-on-force challenges are likely to increase as adversaries seek to take advantage of changes in global power relations resulting from the transition to the Information Age.
- Technological changes make transformation of the military imperative; there is a window of opportunity to leverage U.S. competitive advantage into the future.
- The stakes are very high; if the U.S. fails to transform, current superiority will be increasingly challenged, regional competitors will emerge, and conflict will become more likely.

Transformation of this magnitude does not occur in isolation. The transformation of the military is, in fact, part of the larger transition from the industrial to the Information Age that is occurring simultaneously in societies and economies around the world. This transition is enabled by rapid changes in technologies that precipitate rapid coevolutionary changes in strategies, concepts, processes and organizations.

The Office of Force Transformation (OFT) is chartered to take the lead in moving the U.S. military from an Industrial Age organization to an Information Age organization. It has established six operational goals to focus transformation efforts:

- **Protect** critical bases of operations (U.S. homeland, forces abroad, allies, and friends) and defeat CBRNE weapons and their means of delivery.
- **Assure** information systems in the face of attack and conduct effective information operations.
- **Project and sustain** U.S. forces in distant anti-access or area-denial environments and defeat anti-access and area-denial threats.
- **Deny** enemy sanctuary by providing persistent surveillance, tracking, and rapid engagement with high-volume strike, through a combination of complementary air and ground capabilities, against critical mobile and fixed targets at various ranges and in all weather and terrains.

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[1] President George W. Bush. *Defense Planning Guidance* (DPG) April 2003: pg 3.
[2] *Defense Planning Guidance*: pg 4-6.

- **Enhance** the capability and survivability of space systems and supporting infrastructure.
- **Leverage** information technology and innovative concepts to develop an interoperable, joint C4ISR architecture and capability that includes a tailorable joint operational picture.

## 1.2 Network Centric Theory

The OFT has determined that Network Centric Warfare (NCW) is the core concept that guides the transformation of the U.S. military. NCW is the embodiment of Information Age warfare. It is a new theory of war based on Information Age principles and phenomena, and can be summarized by the *tenets.*[3] These state that a robustly networked force improves information sharing and collaboration, which enhances the quality of information and shared situational awareness. This enables further collaboration and self-synchronization and improves sustainability and speed of command, which ultimately result in dramatically increased mission effectiveness. Figure 1-1 represents the original articulation of the NCW Value Chain.

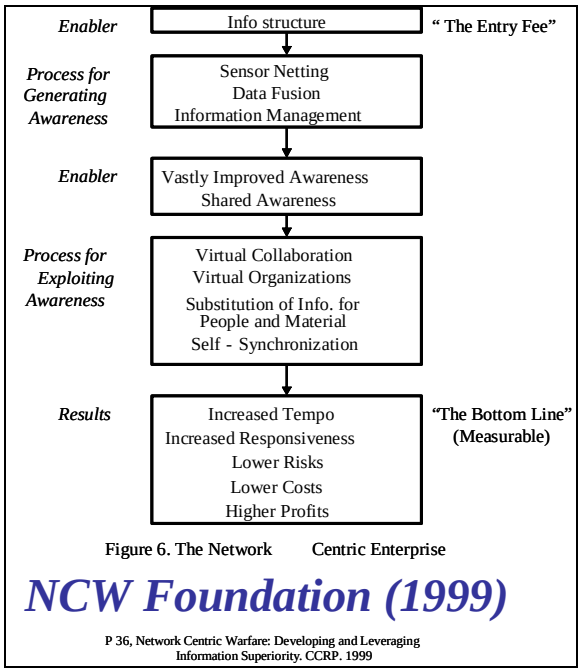


*Figure 1-1. NCW Value Chain*

As part of the efforts to develop and mature the concepts of Network Centric Warfare, the Office of Force Transformation (OFT) and the Office of the Assistant Secretary of Defense, Networks and Information Integration (OASD/NII) have been collaborating on the development of a Conceptual Framework for Network Centric Warfare/Operations (NCW/O)[4] and a variety of other NCO related research, outreach, and publications. Together they have developed a Network Centric Operations Conceptual Framework (NCO CF) for Assessment that identifies

[3] Department of Defense. *Network Centric Warfare Report to Congress*. July 2001.
[4] The Terms Network Centric Warfare (NCW) and Network Centric Operations (NCO) are used interchangeably in this document. However, the latter term (NCO) is preferred because it implies correctly that the theory of Network Centric Warfare applies to a much broader domain of phenomena and is not limited to warfare.

key concepts and linkages to output measures in the Network Centric Warfare value chain in the context of the physical, information, cognitive, and social domains. The framework identifies a vector of attributes for each concept and defines important classes of attributes that are measurable with specific metrics. The initial version of the NCO Conceptual Framework was successfully applied and initially validated using an Air-to-Air combat case study performed by the RAND Corporation. [5]

This document describes the NCO Conceptual Framework for Assessment in detail. Section 1.0 is this Introduction. Section 2.0 provides an overview of the NCO Conceptual Framework and discusses its purpose and limitations. Section 3.0 describes the top-level structure of the framework. Section 4.0 drills down in the Conceptual Framework and describes the attributes and metrics for each top-level concept. Section 5.0 provides a summary and conclusion.

[5] An example of a case study template, adapted from the RAND Air-to-air combat case study, can be found at http://www.oft.osd.mil/library/library_files/document_235_DRAFT_nco_Template_Air_to_Air.pdf/

# 2.0 NCO Conceptual Framework

## 2.1 Overview

The Conceptual Framework is being developed by the Office of Force Transformation (OFT) and the Command and Control Research Program (CCRP) of the Office of the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD/NII) (formerly ASD/C3I).[6]

The objective is to develop a set metrics to assess the tenets of NCW as presented in *Understanding Information Age Warfare*[7] and *Network Centric Warfare*.[8]

In order to develop metrics for the tenets, it is first necessary to identify a "top-level" representation of NCO concepts and their relations. Once the important concepts and their relations are identified, one can then "drill down" and identify attributes and metrics for each concept. The "NCO Conceptual Framework" is the result of that process. While it provides a means to evaluate NCO hypotheses, it also clarifies and illuminates important aspects of NCO theory that were only implicit in the original tenets.

Figure 2-1 is the top-level Conceptual Framework.

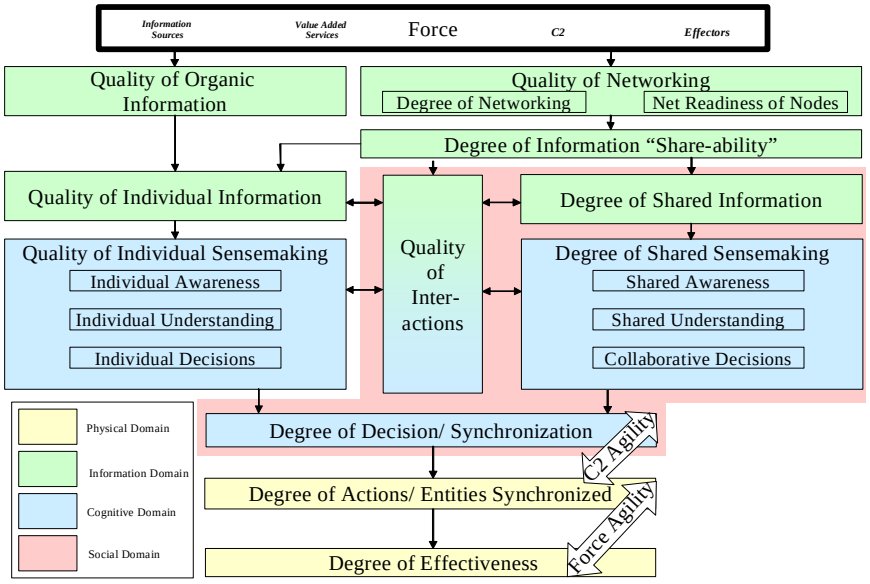


*Figure 2-1. The NCO Conceptual Framework*

Figure 2-4 below represents the evolution of the Conceptual Framework from the original tenets.

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[6] With support of Evidence Based Research, Inc. and the RAND Corporation.
[7] Alberts, David S., John Garstka, Richard E. Hayes, and David T. Signori. *Understanding Information Age Warfare.* Washington, DC: CCRP Publication Series. 2002.
[8] Alberts, David S., John J. Garstka, and Fredrick P. Stein. *Network Centric Warfare: Developing and Leveraging Information Superiority.* 2nd Edition (Revised). Washington, DC: CCRP Publication Series. 2002.

Tenets of NCW (*DoD Report to Congress on Network Centric Warfare*):

- A robustly networked force improves information sharing
- Information sharing and collaboration enhances the quality of information and shared situational awareness
- Shared situational awareness enables collaboration and self-synchronization, and enhances sustainability and speed of command
- These in turn dramatically increase mission effectiveness

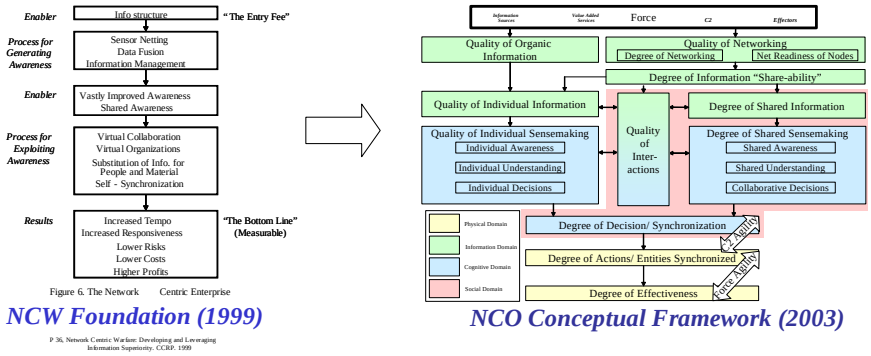



*Figure 2-4. NCO Framework Evolution*

The NCO Conceptual Framework:

- Builds on the tenets of NCW
- Is best understood as a generic "process model"
- Explicitly recognizes the key role of the "social domain"
- Incorporates important research on "sensemaking"
- Identifies key concepts important in most workflow processes
- Identifies potential dependencies among concepts
- Identifies and defines *Attributes* and *Metrics* for each concept
- Is scalable across different levels of aggregation
- Provides a basis for quantitative exploration and/or assessment of
  - NCW hypotheses
  - Investment strategies and other DOTML-PF related issues

### *2.1.1 Innovations of the Conceptual Framework*

Network Centric Operations is not about hardware and routers—it is about people, organizations, and processes. The Conceptual Framework highlights the fact that network centric operations cut across several domains: physical, information, cognitive and social. The central role of social interactions (including collaboration) is evident in the Conceptual Framework. While the original NCO work highlighted the physical, information, and cognitive domains, the most recent work introduces the social domain as an important element. The framework also distinguishes between individuals and "groups" (teams, organizations, etc.). This is an especially important innovation as future operations are expected to be joint and involve interagency coordination and international partners.

Development of the Conceptual Framework also led to the emergence of Agility as an especially important concept for Network Centric Operations. Agility captures the essence of transformation and is highlighted in the top-level diagram as C2 Agility and Force Agility. Agility refers to the ability to be robust, flexible, responsive, innovative, resilient, and adaptive.[9]

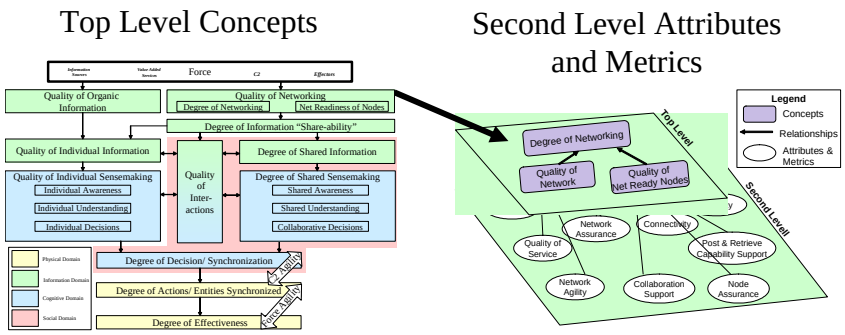
An important innovation that emerged is the concept that as the network centricity of the force increases, Mission Capability Packages (MCPs) will co-evolve. MCP elements, such as command arrangements, doctrine, training, etc., will be modified as the transition to an Information Age military organization progresses. The NCO CF provides a means to measure the extent of the co-evolution of MCP elements.

### *2.1.2 Structure of the Conceptual Framework*

Each concept in the top-level is described by a set of attributes and metrics at the second level. The attributes measure characteristics of the concept in terms of quantity (how much? how often? how long? etc.) and quality (how correct? how appropriate? how complete? etc.). Each attribute is actually measured by a metric (or set of metrics) that specifies in detail what data would be needed to measure the attribute. For instance, the "Degree of Networking" is comprised of net ready nodes and the network. In order to assess the impact of various levels and qualities of networking on force performance and outcomes, it is necessary to measure these levels and qualities. For example, as Figure 2-2 illustrates, the attributes of net ready nodes are: Capacity, Connectivity, Post and Retrieve Capability Support, Collaboration Support, and Node Assurance. The attributes of the network are: Reach, Quality of Service, Network Assurance, and Network Agility. In order to gather data to assess each of these attributes, specific metrics are needed. The Conceptual Framework provides metrics for each attribute. For example, Network Reach can be measured by the percentage of nodes that can communicate in desired access modes, information formats, and applications.

[9] Section 4.1.5 below discusses Agility in some detail.

# NCO Conceptual Framework
# Top level and Second Level




Each Concept in the Top Level is Mapped to Second Level Attributes and Metrics

*Figure 2-2. Top Level and Second Level View*

The framework is a rich set of metrics that can be utilized to evaluate the impact of various levels and qualities of important NCO concepts, such as the degree of networking, on individual and shared information, situational awareness, understanding, decisionmaking, synchronization of actions and ultimately effectiveness. The NCO Conceptual Framework can be utilized in a variety of ways. For instance, it can be used as a tool to evaluate force performance in exercises and experiments; it can also be used to guide policy development and acquisition decisions. In order to evaluate the relationships among the concepts, it is necessary to establish specific hypotheses that link the top-level concepts and second-level attributes. Figure 2-3 illustrates this step.

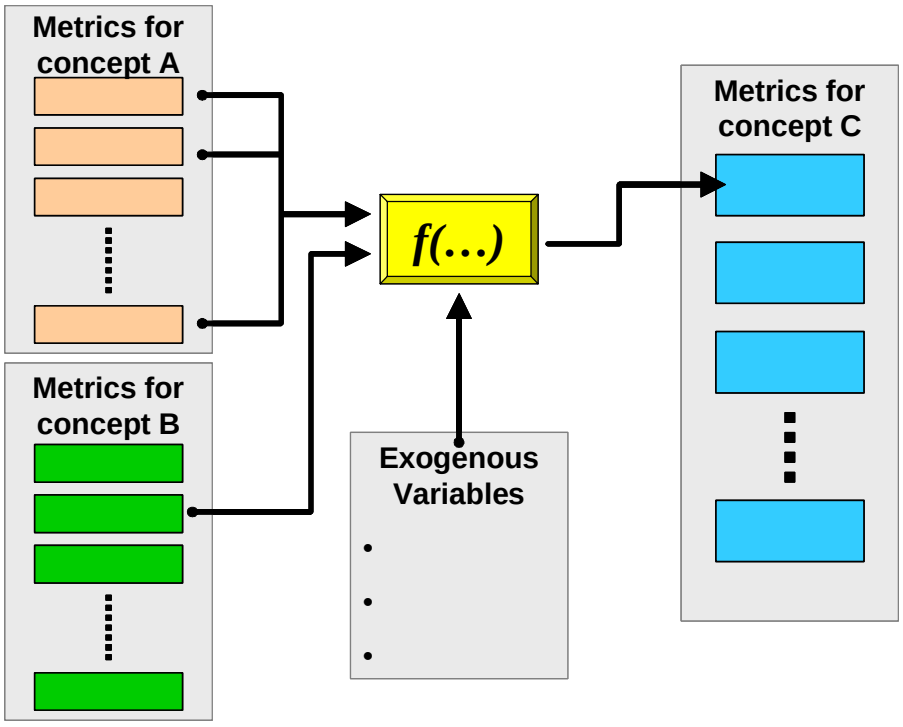



*Figure 2-3. Relationships among Concepts*

### *2.1.3 Application of the NCO Conceptual Framework*

In order to validate and refine the conceptual framework, it must be applied to a broad range of mission areas across the range of possible military operations. It should be vetted across the DoD, allied, and coalition military partners, as well as other Government agencies so that improvements and refinements can be made. The more mature NCO CF can then be used as an assessment tool and metrics guide to inform experimentation, acquisition, and other Transformation related activities. These activities form the core of the Network Centric Operations Conceptual Framework Program, a current initiative of the Office of Force Transformation.

### *2.1.4 Air-to-Air Example*

In an initial test of concept, the NCO Conceptual Framework was used to evaluate the results of air-to-air training sorties in a major training exercise. Over 12,000 training sorties were conducted using two distinct information systems: voice only and voice plus link-16.[10] The voice plus link-16 system is illustrative of a "networked" force in that all force members shared voice and data over the network. The voice only system allowed for information sharing via voice links only and had no data-sharing capabilities. The kill ratio was over two and a half times higher for the "networked" system vs. voice only.

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[10] *JTIDS Operational Special Project (OSP) Report to Congress, Mission Area Director for Information Dominance, Office of the Secretary of the Air Force for Acquisition*. Washington, DC: Headquarters U.S. Air Force, December 1997.

The RAND research team developed an Analytica model to estimate values for selected NCO metrics and aggregate them into the values of the top-level concepts. As Figure 2-3 illustrates, while both systems started with the same "quality of organic information" the degree of networking, quality of shared information, awareness, understanding, decision making and effectiveness diverged significantly between the two systems.

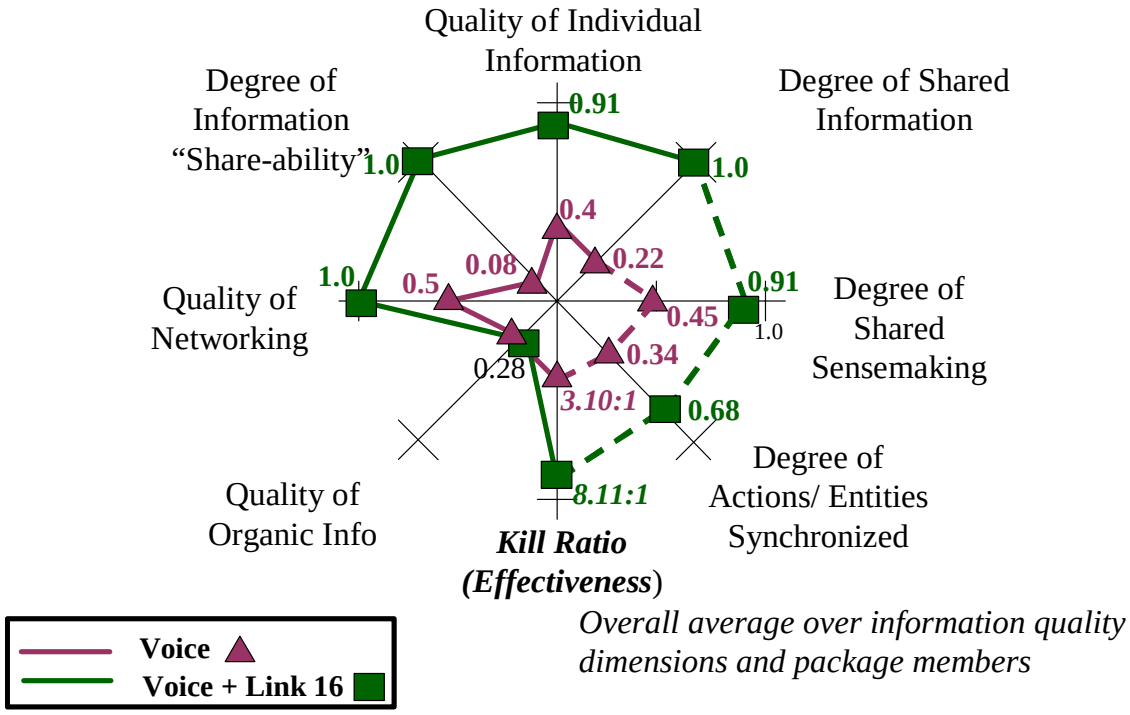


*Figure 2-3. Comparison of MCPs across Voice and Voice Plus Link 16 Systems*

### *2.1.5 Limits of the NCO Conceptual Framework*

It is important to explicitly identify the limitations of the NCO CF. First and foremost, the NCO CF is a work in progress. This document is the initial articulation of the theory and thinking behind the CF. Future versions are expected. Second, the NCO CF is best thought of as an assessment tool that, in order to be useful, must be applied in a specific context. As the Conceptual Framework is used in experiments, investments analyses, and applied to case studies, evidence will be accumulated that will enable us to specify the conditions under which NCO hypotheses are supported. Until that time, however, the Conceptual Framework is "neutral" in that it is not a prescriptive guide, that is, it does not tell us "what to do" in order to become more net-centric. It does not tell us "how much" is enough in terms of network-centric technologies and practices. The Conceptual Framework will, however, facilitate the collection of the evidence needed to answer such questions.

# 3.0 NCO Conceptual Framework: Structure

## 3.1 Overview

While the NCO Conceptual Framework should be seen as mechanism to assess the structure and processes inherent in command of future military forces and control of those same forces in an operating environment, it can also be understood as a set of tightly coupled concepts and relations. The top level view (Figure 2-1) has been developed to show those factors considered most important. However, NCO is a rich and evolving set of ideas, so some significant features have necessarily been captured in the second layer (attributes and metrics). Moreover, because the Framework remains a work in progress, all the top level concepts and the relationships shown between them (either by arrows or by "nesting" some concepts inside others) must be understood as hypotheses subject to disconfirmation or improvement (by improved definition, discovery of limiting conditions, merging some ideas and distinguishing others, or by "discovering" [deciding as a community] that other concepts must be included).

## 3.2 Domains

In order to understand Network Centric Operations, it is essential to recognize that military entities and activities are located in four domains: the physical, information, cognitive, and social domains. The first three domains are discussed in detail in *Understanding Information Age Warfare*. [11] The physical is where strike, protect, and maneuver take place across the environments of sea, air, and space. The information domain is where information is created, manipulated, value-added and shared. It can be considered the "cyberspace" of military operations. The cognitive domain is where the perceptions, awareness, understanding, decisions, beliefs, and values of the participants are located. These intangibles are crucial elements of network centric operations.

The social domain is an innovation of the NCO Conceptual Framework. It is where force entities interact, exchanging information, awareness, understandings and making collaborative decisions. It overlaps with the information and cognitive domain but is distinct from both. Cognitive activities by their nature are individualistic; they occur with in the minds of individuals. However, shared sensemaking, the process of going from shared awareness to shared understanding to collaborative decisionmaking, can be considered a socio-cognitive activity in that individual's cognitive activities are directly impacted by the social nature of the exchange and vice versa.

The social domain, as a recent innovation to network-centric theory, will require additional research and thinking. Section 4.2 below discusses shared sensemaking in some detail and provides additional insight into the social domain.

These four domains are represented in the NCO Conceptual Framework by the color scheme illustrated in Figure 3-1.

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[11] *Understanding Information Age Warfare:* pg 10-14.

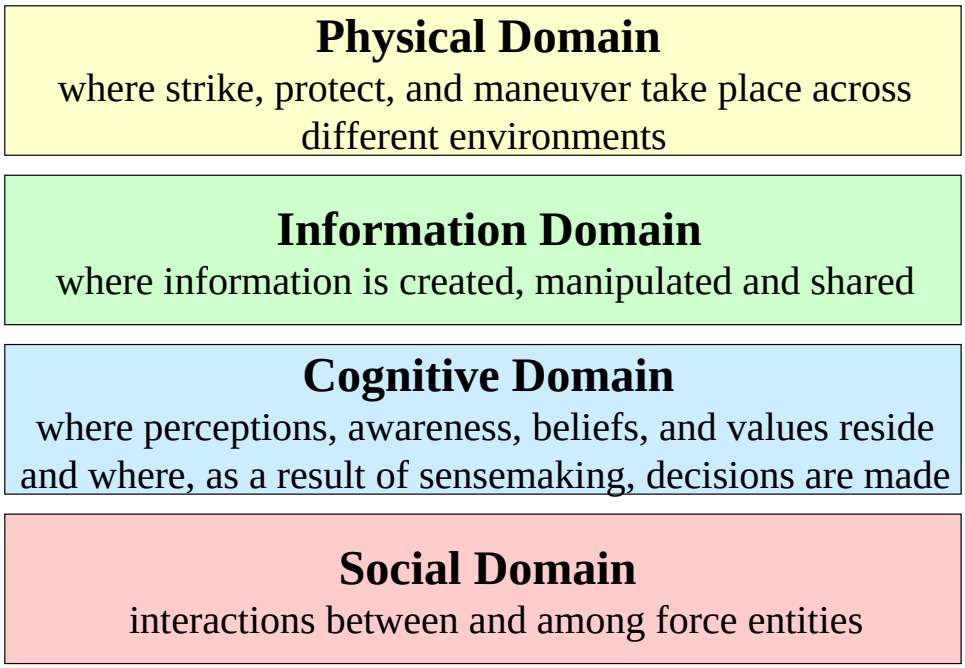


*Figure 3-1. The Four Domains*

## 3.3 The Force

The Force is not in any one of the four key dimensions (physical, information, cognitive, or social) because it is both in them all and also contains elements of all of them. The Force, in this framework, is made up of entities that provide four basic kinds of functions (see Figure 3-2):

- Effects – those elements of the force that play a role by impacting the operating environment. These certainly include weapons, but they also include information entities such as psychological operators and media spokespersons, electronic and cyberspace warfare entities, and those responsible for diplomatic, economic, and other effects.
- Information Sources – force elements that collect or generate information relevant to operations. These include sensors of all types, human intelligence, and organizations that collect relevant information from open sources (news reports, web sites, etc.).
- Value added services – those elements that fuse data or information, add knowledge to help understand or interpret data, information or other knowledge, respond to queries, or define needs for new data or information.
- Command and control – those force elements that perform or support the command function or the control function, including decision support tools.

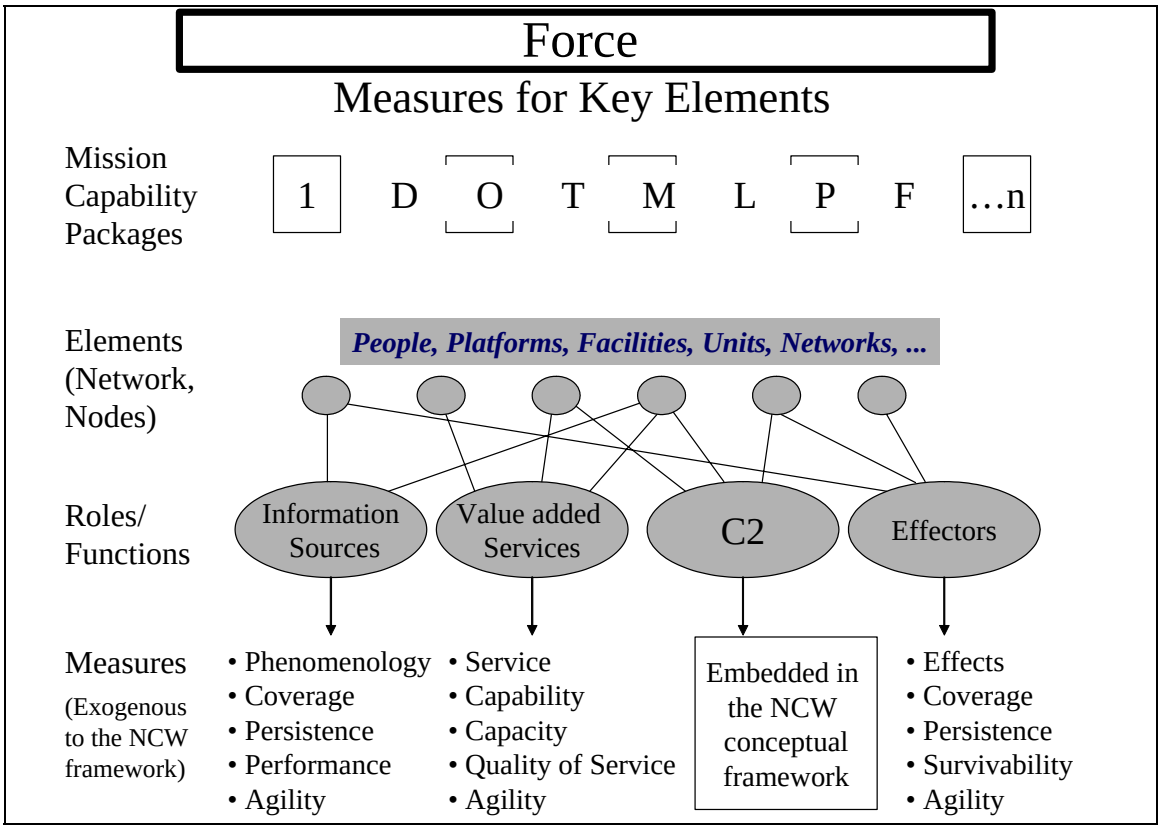


*Figure 3-2. Relationship of MCPs to the Force*

A single platform, work station, or headquarters may perform more than one of the four roles in the force. An aircraft carrier, for example, will typically include sensors, value-added services, C2, and effectors in the same operation. With the changing nature of the strategic environment, U.S. force entities will increasingly be required to be effective across a broader range of functions. This will require agility.

## 3.4 NCO Value Chain

The tenets of NCW state that a robustly networked force will ultimately result in dramatically improved mission effectiveness. The intervening steps that lay between a change in the network centric capabilities of the force and mission outcomes can be considered the NCO "Value Chain." The value chain actually is a way to represent key hypotheses of network centric theory. An important goal of the NCO Conceptual Framework is to allow researchers to collect evidence (using a set of metrics) on these hypotheses so that they can be evaluated scientifically. The Conceptual Framework, then, can be considered an elaborated NCO Value Chain. Figure 3-3 illustrates how the NCO CF can represent the NCO Value Chain in the RAND Air-to-Air example.

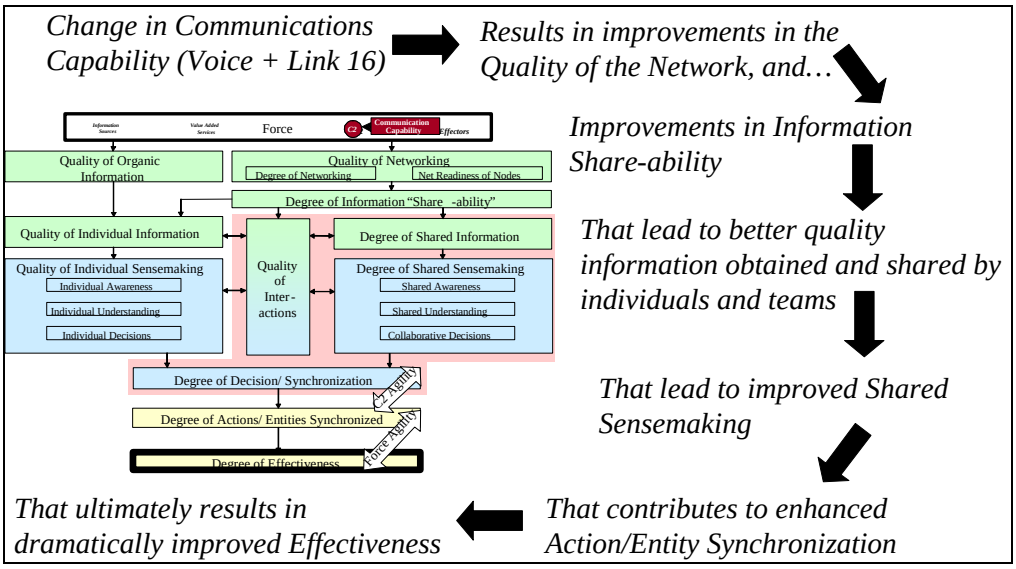


*Figure 3-3. The NCO Value Chain Storyline*

## 3.5 Top Level Concepts

The NCO Conceptual Framework is comprised of the following top-level concepts:

- Quality of Organic Information
- Quality of Networking
- Degree of Information "Shareability"
- Quality of Individual Information
- Quality of Individual Sensemaking
- Quality of Interactions
- Degree of Shared Information
- Degree of Shared Sensemaking
- Degree of Decision/Synchronization
- Degree of Actions/Entities Synchronized
- Degree of Effectiveness
- C2 Agility
- Force Agility

This compares to the seven concepts specified in the original Tenets:

- Robustly networked force
- Information sharing
- Collaboration
- Quality of information
- Shared situational awareness
- Self-synchronization
- Sustainability and speed of command

There is an obvious trade off between simplicity and complexity in the representation of the NCO Value Chain. For some applications, such as those for senior level decision makers or broad non-DoD audiences interested in learning about NCO, a simplified presentation such as the original tenets is preferred. For applications, such as case studies, experiments, or specific acquisition decisions, a more detailed and complex representation is required. The NCO Conceptual Framework, in its current state, is intended for the latter audience. It is meant to provide guidance to researchers and decision makers conducting experiments, case studies, and making specific acquisition decisions and as such in necessarily complex.

## 3.6 Attributes and Metrics

In order to assess the impact of network centric technologies on each of the top-level concepts in the NCO Value Chain, it is necessary to use a *set of attributes* that allow us to assess the different characteristics each top-level concept. Likewise, each attribute can be measured with a specific metric, or set of metrics.

Assessing the "dependent variable," mission effectiveness, requires that we consider that particular concept in the context of a set of measures of effectiveness. It is useful to think in terms of a hierarchy of measures that allow one to measure performance across different levels of the relevant outcome space. The following hierarchy of measures is adapted from the *NATO Code of Best Practices for C2 Assessment*: [12]

- Measures of Policy Effectiveness (MoPE), which focus on high-level policy outcomes;
- Measures of Force Effectiveness (MoFE), which focus on the extent to which a force achieves its mission/objectives;
- Measures of C2 Effectiveness (MoCE), which focus on the impact of C2 on outcomes; and
- Measures of C2 Performance (MoCP), which focus on internal characteristics of C2 programs, initiatives, system(s), etc.

In determining what attributes are appropriate, it is necessary to begin with the concepts of interest and their definitions. Attributes must provide a means of measuring the actual concept as specified in the definition. Similarly, metrics must be selected that actually allow one to measure the concept of interest. Otherwise, our attributes and metrics would not be *valid* indicators of the values of the concepts. In addition, metrics should be *reliable*, that is, they are specified with the appropriate level of clarity and detail that multiple attempts (by different researchers) to measure an attribute using a given metric will result in the same value for the attribute.

It is helpful to identify broad classes of attributes that can be utilized in such an effort. These include: objective attributes, fitness-for-use attributes, agility attributes, and other concept specific attributes. These are defined below.

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[12] Stenbit, John P., Linton Wells, II., & David S. Alberts. *NATO Code of Best Practice for C2 Assessment*. Washington, DC: CCRP Publication Series. 2002: pg 92.

**Objective Attributes** measure quality in reference to criteria that are independent of the situation. For example, the *currency* of a given data element indicates the age of the information available and can be expressed in units like minutes, hours, days, etc.

**Fitness-for-Use Attributes** measure quality in reference to criteria that are determined by the situation. For example, the *timeliness* of a given data element indicates the extent to which the information is received in a time that is appropriate for its intended use. What is appropriate is context dependent. In some contexts a currency of two hours is adequate, where as in other contexts a currency of two minutes is what is needed. Fitness-for-use attributes allows one to capture information that is context dependent.

**Agility Attributes** measure the aspects of agility across the six dimensions. These attributes inherently are comparative, i.e. agility implies an ability to change over time and, as such, the values of the metrics for these attributes have to be compared to some baseline values.

**Concept Specific Attributes** measure unique aspects of some concepts. For instance, synchronicity is an attribute of the Quality of Interactions concept that measures the extent to which C2 processes are effective across time (synchronous vs. asynchronous) and space (co-located vs. distributed). This attribute is appropriate in determining the extent to which elements in a C2 organization can interact simultaneously in time and space but is not necessarily relevant to other concepts.

Attributes will likely be measured by metrics that are subjective (qualitative) as well as those that are objective (quantitative). Whenever possible, quantitative metrics should be utilized, and the goal is to increasingly rely on quantitative metrics. However, there are circumstances when qualitative metrics are appropriate and necessary. Qualitative metrics should be built on clearly articulated criteria identified by subject matter experts, or determined by existing theory and/or empirical observations.

It is important to keep in mind that summary attributes (and metrics), aggregated across programs, initiatives, systems, etc., are often utilized in high-level comparative assessments. In such cases, attention to standard multi-attribute measurement methods is essential. Most importantly, the level of precision of the aggregate metrics cannot exceed the level of precision of the least precise input metric.

Another important issue to consider is the distinction between metrics and objectives. Metrics are the yardsticks that we use to measure aspects of attributes. Objectives are the performance/quality goals. For instance, the attribute *completeness* is the extent to which shared understanding incorporates all relevant information and possible outcomes. The metric could be measured in percentages. An objective may be 80% or 95%, for example. The metric is what is being measured; the objective is some goal that must be determined by policy, experimentation and/or analysis.

Figure 3-4 illustrates the relationship between concepts, attributes and metrics for the concept Quality of Organic Information.

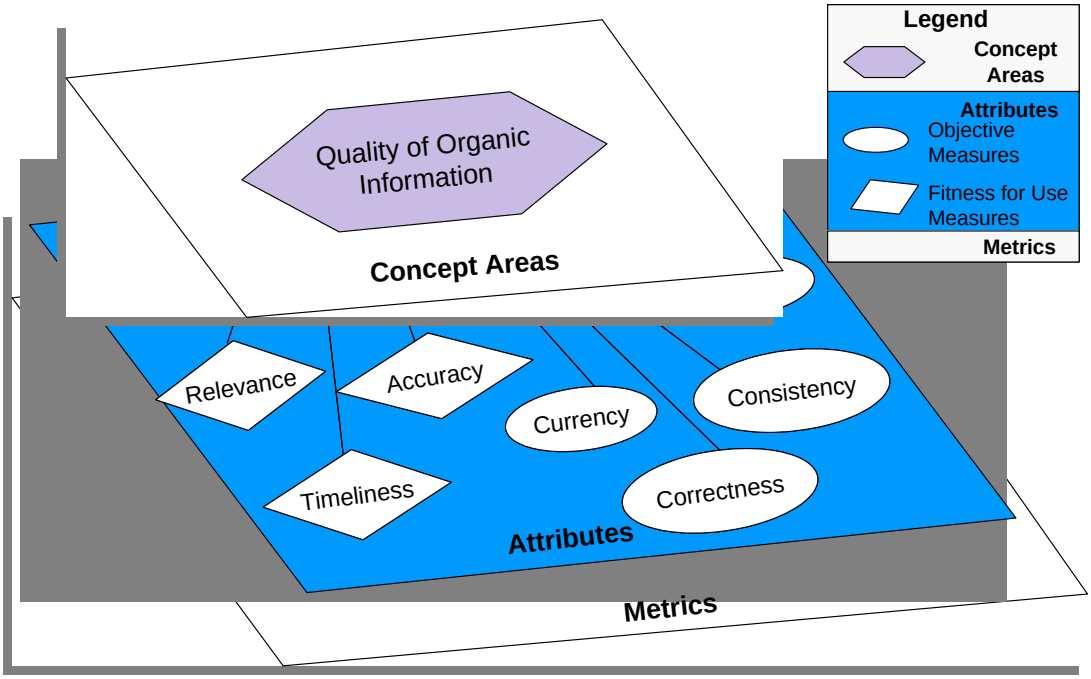


*Figure 3-4. Quality of Organic Information*

# 4.0 NCO CF Concepts, Attributes, and Metrics in Detail

This section provides detailed descriptions of each of the major concepts in the top-level of the NCO Conceptual Framework. Following the guidance of the *NATO Code of Best Practice for C2 Assessment*, it starts "at the bottom" of the NCO Conceptual Framework with a description of the "dependent" variables in the NCO Value Chain: Synchronization, Agility, and Effectiveness. It then discusses the concepts that trace out the value chain from networking and information, through Sensemaking, and Quality of Interactions. This section concludes with a summary and synthesis of the approach taken to relate concepts, attributes and metrics.

## 4.1 Synchronization, Agility, and Effectiveness

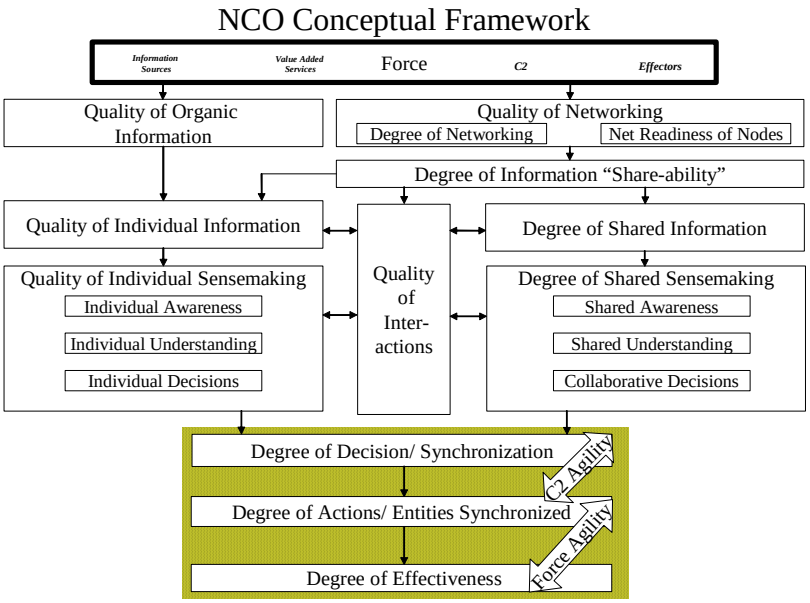


*Figure 4-1. The NCO Conceptual Framework*

### *4.1.1 Decision Synchronization*

Stated most simply, decisions are choices among alternatives. In the context of the NCO Conceptual Framework, they may take place across multiple levels of command: from command intent generated at the most senior level and disseminated to all levels and across all functions to selection of courses of action across echelons, functions, organizations (including coalition partners and non-military organizations involved in missions with the military, particularly when effects-based operations are explicitly considered), to tactical decisions ranging from weapons-target pairing to when contingencies should be activated.

Many decisions, particularly in Industrial Age militaries, or the Industrial Age legacy parts of Information Age militaries, are expressed as plans. Military plans may be more or less detailed, but they always include or imply six elements:

- Missions – what is to be accomplished;

- Assets – which resources (including elements of the force) are assigned or available for each mission or military task;
- Command Arrangements – what are the organizational relationships among the elements of the force and between the force and other organizations that the force depends upon;
- Boundaries – which organizations are responsible for and have authority over what geographic regions (land, air, maritime, and space) and functions;
- Schedules – how are missions and assets organized over time; and
- Contingencies – explicitly recognizable situations under which missions, assets, command arrangements, boundaries, or schedules will change.

Explicit, written plans are not essential in all military operations. In many dynamic situations, particularly in Information Age militaries with very flat organizational structures and doctrines that encourage self-synchronization, plans may be largely implicit, expressed very briefly, and depend on prior training and shared mental models. For example, in the NCO Conceptual Framework Air-to-Air combat case study RAND conducted on the effect of Link 16 on combat power, pilots were able to synchronize their tactical actions with a minimum of discussion because of their prior training and shared command intent allowed the participants to effectively and efficiently integrate the shared information provided by the Link 16 system to form shared understanding of the battles space.

### *4.1.2 Action/Entity Synchronization*

Synchronization, the third key element in this conceptual area, is defined as "purposeful arrangement in time and space." While a rich concept, its meaning in the context of future command and control has thus far been confined to a single dimension with three defined scale points (see Figure 4-2):

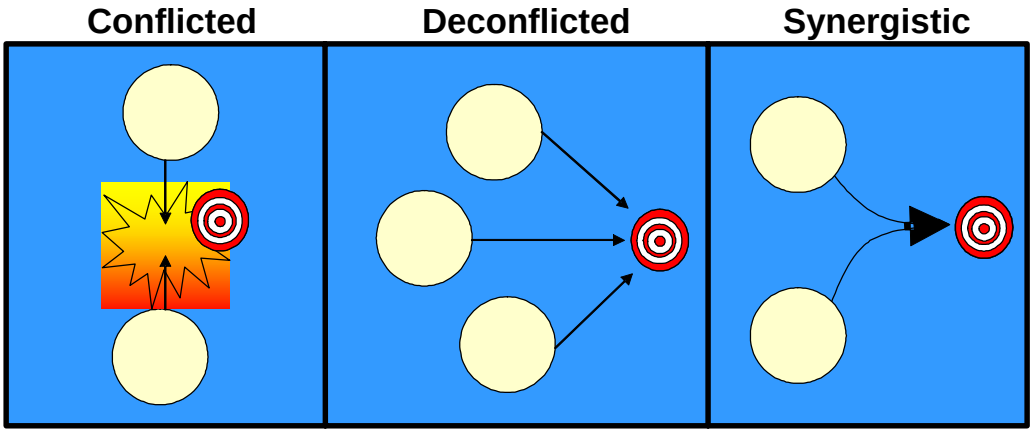


*Figure 4-2. Synchronization Categories*

- Conflicted – two actions or entities interfere with one another. The classic case of conflicted actions is casualties due to friendly fire. Another good example is traffic jams when logistics trains from two forces block one another's routes.
- Deconflicted – actions or entities that are prevented from interfering with one another by separation in time, space, or both. Most classic military control measures from the Industrial Age are deconfliction tools. Ground units are given specific areas of

responsibility, no-fire lines are established to prevent fratricide, roads are reserved for the exclusive use of particular organizations, fixed wing aircraft and rotary wing aircraft are assigned different altitudes, etc.

- Synergistic – actions and entities that reinforce one another's desirable impacts on the operating environment. For example, the ability to strike suddenly and fiercely without warning (precision guided munitions delivered at night from high altitudes or by stealth aircraft) may be synergistic with carefully designed leaflets because together they yield larger numbers of surrenders and desertions than either of them would produce alone. More traditionally, combined arms teams can accomplish missions that no single arm (infantry, armor, artillery, and aviation) can achieve independently.

### *4.1.3 Measuring Synchronization of Decisions and Plans*

There are four dimensions across which the synchronization of decisions and plans can be measured – entities, expected actions, plan elements, and time. No single attribute is a perfect measure for synchronization and they may well interact. In particular, time may be a control factor for entities, actions, and plan elements. The four attributes are really just four different perspectives on synchronization during the process of integrating decisions or creating plans.

The crucial decision an analytic team must make is the level of detail at which measurement will be made. The simplest case is that of entities. In any battlespace or operating environment there are a number of different levels at which entities can be counted, including not only echelon, but also function. So, decisions or the plans that embody them can be counted at any of those levels. However, selecting a level then implies the ability to operationalize that level as well as count consistently. If, for example, the entities selected are combat flights of aircraft, then all combat flights must be counted, and only those related to combat flights, not flights for other purposes. If the level selected for a ground combat effort is the company, then its equivalents must be understood in terms of other types of entities (for example, artillery batteries). Deciding equivalence will sometimes be difficult if the entities involved are heterogeneous. For example, naval forces are organized very differently from air and ground forces, so deciding the level of analysis for an amphibious operation may require considerable thought. Identifying peers in functional relationships is probably a good way to organize this problem.

Equivalent decisions must also be made for plan elements, actions, and the timesteps to be used in measurement. Plan elements (missions, assets, command arrangements, boundaries, schedules and contingencies) are often controlled by considering the number of entities they include, so mission assignment is the number of missions times the number of entities tasked to conduct and support that mission. Similarly, expected actions can be controlled for the number of entities anticipated to participate in or support them.

### *4.1.4 Relevant Metrics*

Looked at through these lenses, the metrics for decision and plan synchronization will be computed as:

- The percentage of entities included in decisions that are conflicted, deconflicted, or synergistic;

- The percentage of plan elements that are conflicted, deconflicted, or synergistic;
- The percentage of expected actions that are conflicted, deconflicted, or synergistic; and
- The percentage of time that decisions and plans (seen as two representations of the same thing) are conflicted, deconflicted, or synergistic.

Note that conflicted entities, plan elements, expected actions, and periods of time are always negative. They literally represent the fog and friction of war in this portion of the NCO Conceptual Framework. Similarly, synergistic entities, plan elements, expected actions, and periods of time are always good. However, note that some synergy can be better than other synergy because the value of synergy is not absolute, but is derived from its impact on effectiveness. Finally, deconfliction is always better than being conflicted and, by definition, less valuable than synergy. However these differences are ordinal (there is no way to measure the difference between the three values). In theory, deconfliction may be barely better than being conflicted or just short of being synergistic.

Future challenges in this area include: (a) establishing the relationships between synergy in decisions and plans in the cognitive domain and synchronization of actions and entities in the physical domain as well as with effectiveness, and (b) developing more precise ways of measuring synchronization. The three-part scale used now (conflicted, deconflicted, and synergistic) appears valid and reliable, but has limited precision. The existing scale also appears to have credibility with military professionals and analysts in large measure because it is transparent (easily understood and expressed in examples). Better measurement approaches will need to preserve the validity, reliability, and credibility of the current system while providing greater precision. Case studies and other research (particularly properly focused simulations) should help to establish the correlation (or lack of correlation) and conditions influencing the relationship between synchronization in the cognitive domain and both effectiveness and synchronization in the physical domain.

### *4.1.5 Degree of Action and Entity Synchronization*

Moving to the physical domain, the concept of synchronization remains unchanged – purposeful arrangement in time and space. There are three relevant dimensions – entities, actions, and time. The same fundamental analytic problems remain, especially the need to identify and apply a level of analysis consistently and to make time a meaningful control. The implied metrics are:

- The percentage of entities that are categorized as conflicted, deconflicted, and synergistic;
- The percentage of actions categorized as conflicted, deconflicted, and synergistic; and
- The percentage of time that the force is classified as conflicted, deconflicted, and synergistic.

This last metric may be very difficult to operationalize outside the context of entities or actions, so time may be best considered as a control, making the metrics of interest the *rate* of conflicted actions or entities over units of time. This may well be the best way to approach synchronization in a dynamic environment where entities may change their degree of synchronization over time (move in and out of the three categories) and actions will have a temporal focus. Of course, the "snapshot" approach may also be useful. This technique would call for assessing the state of

synchronization at selected points in time, which might be identified because of their substantive importance (just prior to hostilities, two hours after a major attack by the red forces, etc.), at systematic points in time (every four hours), or on the basis of a stratified sample.

### *4.1.6 Degree of Effectiveness*

Effectiveness always deals with impact on the operating environment. The MORS (Military Operations Research Society) work on measures of merit during the early 1980s has been widely accepted in the C4ISR analytic community. It has been most recently integrated in the *NATO Code of Best Practice for C2 Assessment* and has been used by JFCOM and others in significant experiments. It recognizes three levels of Measures of Effectiveness (MoE), Measures of C2 Effectiveness (MoCE), Measures of Force Effectiveness (MoFE), and Measures of Policy Effectiveness (MoPE). This last category was added by a NATO Studies and Analysis panel working group (SAS-026) in recognition of the fact that military performance does not guarantee accomplishing the larger missions implied in effects-based operations (peacekeeping, nation building, etc.). That working group included U.S. members who had helped develop the original MORS taxonomy.

The three categories can be distinguished by an example. The context is a carrier battle group positioned off the shore of a friendly state (The Republic of Goodness) that has been invaded by a neighbor (The Kingdom of Badness). Badness posses medium range bombers equipped with cruise missiles. The ability of the C2 system supporting the battle group to identify potential threat platforms early enough to position defensive platforms (aircraft and vessels) where they can intercept and engage them beyond the stand off range of the cruise missiles is an indicator of C2 effectiveness (MoCE). This might be measured by how rapidly threat platforms can be identified and plans developed and implemented to intercept them and how correct is the identification, and so forth.

However, the C2 system cannot engage platforms in the physical domain. That is accomplished by effectors. The correct MoFE (measures of force effectiveness) involve adversary kills, mission aborts by platforms that launch beyond effective range or break off before launching, and casualty ratios. The “kill ratios” employed by RAND in the initial air-to-air case study in support of the NCO Conceptual Framework are MoFE. In the event that the efforts to protect the carrier battle group result in shooting down innocent aircraft by accident and therefore reducing support for the coalition and endangering the mission, then MoPE (Measures of Policy Effectiveness) have been impacted.

Most of the MoCE, in applying the NCO Conceptual Framework, will occur in the sensemaking conceptual arena. However, analytic teams should also be alert to the possibility that the C2 systems (human and machine) involved in a particular operation, exercise, or simulation may cause physical movement of force elements. This will appear in the synchronization metrics and signal that MoFE should be applied.

Effectiveness metrics share with synchronization metrics the need to identify an appropriate level of analysis. When applying the NCO Conceptual Framework at the tactical level, that is when it is used to evaluate specific case studies or utilized in specific experimentation efforts, the key units are clearly missions. Missions may be combat missions, combat support missions or

missions in which the military supports others (humanitarian missions, support to law enforcement, non-combat evacuations). However, there will often be layers of missions assigned to different elements of the force (entities), in different functional areas (logistics, intelligence, etc.), and over time. Hence the degree of mission accomplishment may differ across these arenas and the relevant metrics will include both assigning values to individual metrics and "roll up" calculations that create mission accomplishment indices. As with synchronization metrics, time or periods of time may need to be considered. In past analyses, sampling has been used as has assessment based on phases of the mission (pre-deployment, deployment, movement to contact, combat by phases, conflict termination). However, not all military missions will be organized in this way.

Some missions have relatively straightforward or direct measures. For example, the RAND air combat case study simply used loss ratios to assess the effectiveness of the entities. However, analysts should be cautious when developing or selecting MoFE because they may miss important distinctions. For example, when assessing success in interdicting drug movements "successes" include not only captured or destroyed loads, but also aborted missions that forced the smugglers to return with their load. These aborted missions are not fully successful in that they do not result in removing the drugs from the pipeline. However, they do mean that smugglers must try again to complete the movement (providing another opportunity at fully successful interdiction) and often yield intelligence about where the load was diverted, identifying smuggling bases or transit points. Indeed, aborted missions may also create pressure within the smuggling organizations that lead them to take chances, open up new routes, or attempt new means of smuggling, all improving the chances of successful interdiction. Hence, ignoring the "abort" cases would give a false picture of the impact of interdiction efforts.

Similarly, analysts must be aware of MoPE when designing or selecting the ways they will measure effectiveness. For example, recent Army experiments with Information Age command and control concepts introduced the possibility of neutral casualties into their scenarios and even kept track of them. However, the analytic team chose to measure effectiveness only including force (red and blue) casualties. As an unintended consequence, the "players" probably did not value neutral casualties as much as they might have in a "real" combat situation. At a minimum the results of these experiments will need to be reanalyzed to make useful estimates of the extent to which policy objectives (which often depend on attitudes among the neutral populations) were being compromised in these experiments.

Mission accomplishment not tied to physical objectives or performance characteristics (take the hill before 1400, move 425 tons of artillery ammunition into forward supply depots before August 14) can be difficult to assess objectively. Where direct observation is possible, scoring should be simple (i.e., 1 for mission accomplishment, 0 for failure to accomplish the mission, aggregated over missions to create an index). Some techniques that have been employed successfully in the past when direct measurement is not possible include:

- Independent ratings by panels of subject matter experts; and
- Convergence techniques using group software.

Use of selected Subject Matter Experts (SMEs) to score effectiveness has been used in cases where a modest set of resources were available. For example, in a multinational limited objective

experiment organized by JFCOM to examine hypotheses about alternative methods of planning in coalitions, five flag officers (active duty and retired) from three different nations were used to assess the quality of the plans produced using different procedures and organizational structures. These officers met with the experimentation team to discuss the scenario being used, discussed alternative approaches (command intent and courses of action) among themselves, and worked independently to develop their assessments. Their scoring was "blind." That is, they did not know which plan had been developed using which procedures and organizations. The results of their scoring were merged using a voting technique (1 for the top ranked plan, 5 for the bottom) with ties allowed. The results were highly consistent, with little ambiguity about the proper rank order of the plans. However, the results were also ordinal (i.e., ranked) so that it was impossible to determine the size of the differences recorded and cannot be compared with other scoring efforts because of the number of unique factors involved in the scoring (unique SMEs, unique scenario, etc.).

Finally, increasing use is being made in a number of communities of software that encourages discussion and voting among subject matter experts.[13] These tools use a combination of discussion and voting (anonymous in most cases). In a typical example the discussion leader introduces the topic and indicates how the voting will be organized over time and across issues. Discussion follows in which the structure of the process, the meaning of key terms, and the voting procedure are typically addressed. Once the group has had its say (and appropriate adjustments made), voting begins. The results of the first round are displayed to the group and discussion encouraged, particularly on the part of those whose votes are outliers and those representing major positions. Under some conventions, no one is required to speak. Rounds of votes, display, and discussion follow until convergence occurs or alternative positions harden.

Voting and display techniques are attractive when working with genuinely new material (for example nontraditional missions) and when SMEs from very different communities are involved. They can also be useful when developing MoE in complex situations with the expectations that the rules and structures developed will be reused in later efforts. However, they tend to develop relatively unique language, processes, and voting conventions that may not be replicable in other contexts or with other groups, so they should be used with some care.

### *4.1.7 Efficiency and Effectiveness*

Efficiency, defined in classic terms, refers to the cost of being effective. In economics, for example, the classic measure of efficiency is units of output per unit of input or productivity. A more efficient firm or process generates more value (typically measured in dollars) for the same

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[13] An example can be found in: Addison, Tom. E-Commerce Project Development Risks: Evidence from a Delphi Survey. *International Journal of Information Management.* Volume 23, Issue 1. February 2003: pg 25-40. This paper reports on a study to determine the opinion of expert practitioners of the most important risks in the development of e-commerce projects. See also: Madu, Christian, Chu-Hua Kei, Assumpta Madu. Setting Priorities for the IT Industry in Taiwan: a Delphi Study. *Long Range Planning*. Volume 24, Issue 5. 1991: pg 17. Taylor, Raymond, David Meinhardt. Defining Computer Information Needs for Small Business: A Delphi Method. *Journal of Small Business Management*. Volume 23. April 1985: pg 3.

or less cost of input (again usually expressed in dollars). If there is no output, there is no efficiency because there can be no relationship between units of output and units of input. It is like trying to talk about the efficiency of a factory that cannot produce any useful products.

In military terms, the outputs of value are accomplished missions – effectiveness. Hence, the idea of efficiency only makes sense when missions are accomplished. When that occurs it makes sense to consider efficiency in at least three dimensions:

- the size of the force required to accomplish the mission (implicitly, larger forces are more costly and when a smaller force can be used other forces are available to take on other missions);
- the casualties, whether measured in lives and treasure are smaller (forces that accomplish missions with fewer casualties and at less cost to their national treasuries have more capability to take on other, subsequent missions); and
- the time required to accomplish the mission (this is often assumed to be a correlate of fewer casualties and, by definition, it implies that the same force or force elements is available sooner for other missions).

Indeed, the concept of NCO is attractive not only because it is hypothesized to increase the likelihood of mission accomplishment, but also because it is hypothesized to increase the efficiency of the force when compared with those forces that are not network centric. Hence, the NCO Conceptual Framework ought to include measures of efficiency so that these hypotheses can be examined.

### *4.1.8 Agility*

Agility is one of the most important characteristics of successful Information Age organizations. Agility is the ability to be effective in changing, nonlinear, uncertain, and unpredictable environments. Agile organizations are the result of an organizational structure, command and control approach, concepts of operation, supporting systems, and personnel that have a synergistic mix of the right characteristics. The term *agile* can be used to describe each component of an organization's mission capability packages, and/or an organization that can instantiate many MCPs. Since agility is a property of both force elements and C2 processes, the lack of agility in one or more of these components will affect an organization's overall agility. Thus, agile C2 can make much more of a positive difference in the context of an agile force than it would without such a force. However, without an operational concept that utilizes agile C2, the agility of a C2 system (human and equipment) will have only modest benefits. Similarly, an agile force that does not have an agile C2 system and operating concepts, cannot perform close to its capacity.

Agile forces, MCPs, C2 systems, and operating concepts make sense regardless of the threat or the technology environment. However, the more uncertain and dynamic an adversary and/or the environment are, the more valuable agility becomes. Since agility is a property that is manifested over a space (a range of values, a family of scenarios, a spectrum of missions) and time rather than being associated with a point in a space (e.g. a specific circumstance, a particular scenario, a given mission) or time, agility represents capabilities that can be termed scenario independent. While we need scenario independence, traditional military planning is threat-based and relies on

a few likely or most threatening scenarios. Threat-based planning arose because the greatest threat to most countries lay in one or more hostile neighbors (for example, Iran and Iraq in the 1980s). The key to designing agile C2 is representing the diversity of threats and operating environments in a way that samples the future intelligently.

Knowing one's likely adversaries and the nature of their forces, military establishments could study their likely threats and design specific forces, operational concepts, and C2 systems to counteract them. In the past, arms races have provided detailed information about adversary capabilities and intent, leading to counter strategies that are highly specialized to the specific threat. With the changing strategic environment, however, such knowledge of adversarial capabilities and intentions is increasingly difficult to obtain. Rather, U.S. forces must prepare for increased uncertainty and ambiguity in the future.

Therefore, agility is increasingly becoming recognized as the most critical characteristic of a transformed force, with net-centricity being understood as the key to achieving agility. Military establishments have recognized that agility considerations must permeate a mission capability package, not just be considered an attribute of the C2 system, the operational concept, or the force. This implies that the capability to be agile involves having not only the right materiel (sensors, infostructure, and combat systems) but also the right doctrine, organization, personnel, training, and leadership. Moreover, it implies a need to coevolve these MCP elements through experimentation campaigns that assess not only mission effectiveness, but also agility. Indeed, coalition partners are concerned that they need to make the proper near-term investment decisions in order to keep pace with U.S. transformation. The potential for agility is greatly enhanced by the shared awareness and collaboration in Network Centric Operations. In essence, richer information, cognitive, and social domains enable greater agility.

### *4.1.9 Agile C2*

Agile C2 only makes sense in the context of agile forces and operational concepts. Agile individuals (commanders for example may differ in agility), organizations, C2 systems (personnel plus their supporting information systems and decision aids), and forces have a synergistic combination of the following six attributes, the key dimensions of agility:

1. Robustness: Effectiveness across different contexts (the ability to maintain effectiveness across a range of tasks, situations, and conditions).
2. Resilience: Overcoming losses, damage, setbacks (the ability to recover from or adjust to misfortune/damage, and the ability to degrade gracefully under attack or as a result of partial failure).
3. Responsiveness: The ability to react to a change in the environment in a timely manner.
4. Flexibility: Multiple ways to succeed and seamless movement between them (the ability to employ multiple ways to succeed and the capacity to move seamlessly between them).
5. Innovation: The ability to do new things and the ability to do old things in new ways.
6. Adaptation: The ability to change work processes and the ability to change the organization.

While these attributes of agility are analytically distinct and often must be measured in different domains and contexts, in practice they are often interdependent. Therefore, when one of these

attributes is lacking, achieving the others is much more difficult. However, when they are all present, the likelihood of success (mission accomplishment) increases greatly (see Figure 4-3 below). For a complete discussion of the attributes of Agility, refer to *Power to the Edge.*[14]

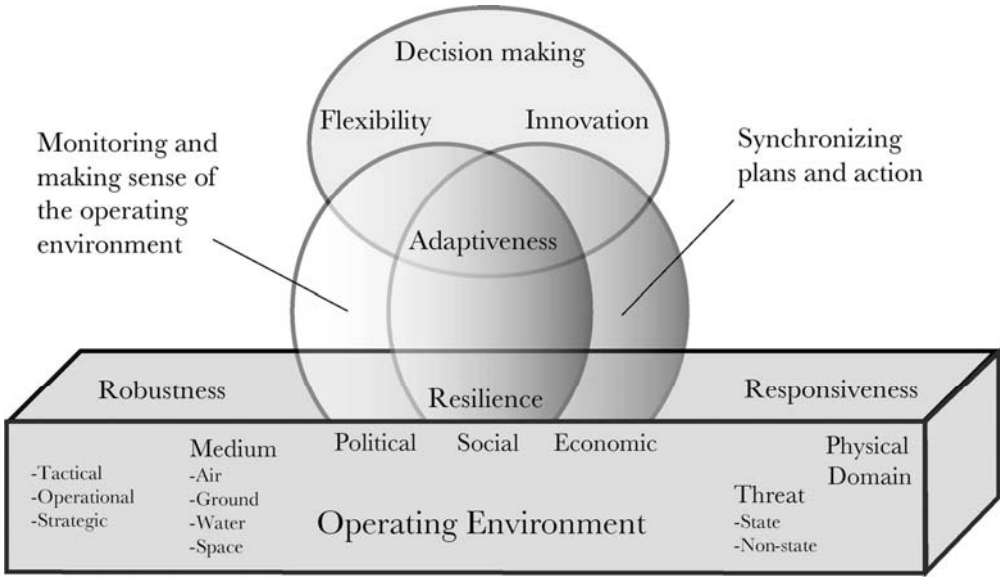


*Figure 4-3. The Six Aspects of Agility in the Domains of Warfare*

## 4.2 Networking and Information

### *4.2.1 Overview*

Networking and information provide the foundation for Network Centric Operations. The tenets of NCW, as reported to the U.S. Congress,[15] begin with the statement: "*A robustly networked force* improves *information sharing*," and end with: "these in turn dramatically increase *mission effectiveness*." The tenets summarize Network Centric Operations as…improving networking capabilities in order to increase mission effectiveness. Thus, networking and information are central to Network Centric Operations. Figure 4-4 below highlights Networking and Information in the NCO metrics framework.

[14] Alberts, David S. & Richard E. Hayes. *Power to the edge: command, control in the information age*. Washington, DC: CCRP Publication Series. 2003.
[15] Department of Defense. *Network Centric Warfare Report to Congress*. July 2001.

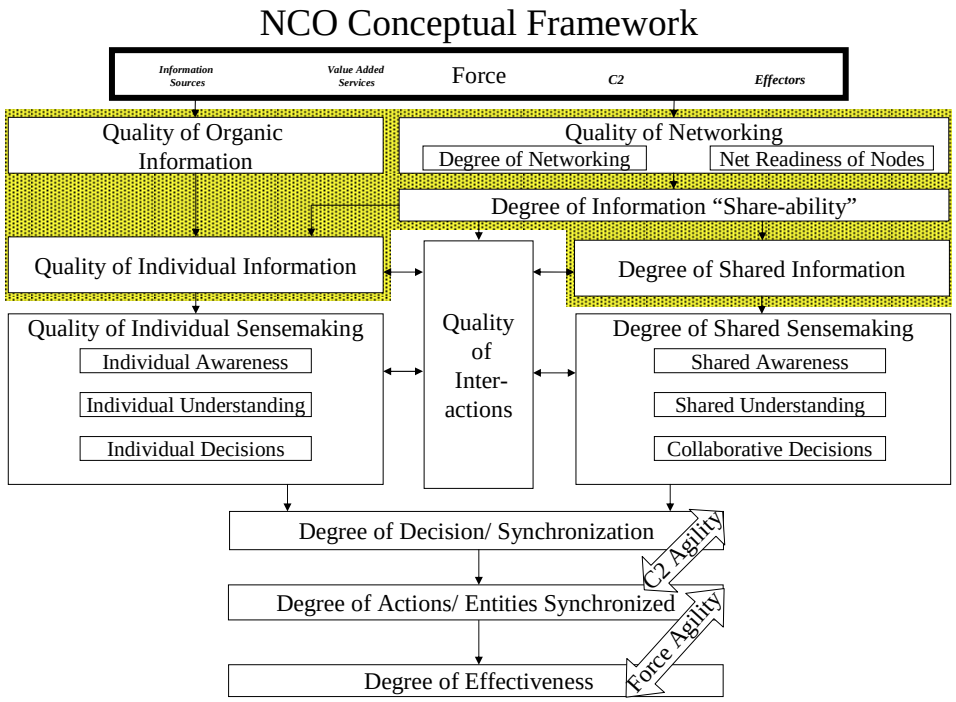


*Figure 4-4. Networking and Information in the NCO Framework*

In *Power to the Edge,*[16] the authors state that as bandwidth becomes less costly and more widely available, individuals and organizations will have direct and simultaneous access to information and to each other and this will facilitate their ability to process information in novel ways. The authors describe a networked collaborative environment as one that "fully enables all of the attributes of reach, richness, and quality of interactions, allowing the utility of the information exchange to be significantly increased, helping to avoid information overload, improve timeliness, facilitate collaboration, and create the conditions for self-synchronization. These information-related capabilities are all enabled by the *post and smart pull* approach inherent to a robustly networked environment."[17]

Information processing occurs in a rapidly changing environment with vast amounts of data. The ability to make informed decisions in such an environment requires that the available data be parsed in such a way as to extract only the specific information needed in real time, e.g. smart pull. The intelligent dissemination of data in a rapid manner is a key indicator of effective network performance.

Evaluating network performance requires an understanding of what network effectiveness means and what issues must be considered. Network evaluation requires a multiple-stakeholder perspective and occurs at three broad levels of analysis: the community, the network itself, and the network's organizational participant levels. While overall network effectiveness depends on interactions across all three levels of analysis, we can evaluate each level separately. Network effectiveness at the community-level is judged by the contribution networks make to the

[16] *Power To The Edge: Command, Control In The Information Age*: pg xiv.
[17] *Power To The Edge: Command, Control In The Information Age:* pgs 81-82.

communities they serve. A network must satisfy the needs and expectations of those groups within a community that have both a direct and indirect interest in seeing that needs are met. Three ways of evaluating network-level effectiveness include: the ebb and flow of agencies to and from the network; the extent to which services that are actually needed are provided by the network; and the strength of the relationships between and among nodes. Two nodes connected in more that one way have a stronger bond than two nodes connected by a single link. Network effectiveness at the organization/participant level is based on four criteria: client outcomes, legitimacy, resource acquisition, and cost.[18]

For example, on a battlefield, commanders are typically viewed as most important, and satisfying their needs is critical for success. However, commanders' needs are likely to be fragmented across echelons, resulting in multiple constituent groups with very different views about how success should be measured. Division-level commanders may have one view of what the network should provide, whereas platoon-level commanders with different requirements may have quite a different view. The Conceptual Framework facilitates measurement of network effectiveness across any given echelon, functionality, etc. by identifying key concepts, attributes, and metrics.

### *4.2.2 Networking*

In information technology, a network is a series of points or nodes interconnected by communication paths. Networks can interconnect with other networks and contain sub-networks.[19] The term "networking" can be thought of as an interconnection of a system of computers, communications, data applications, security, people, training, and other support structures that provide *rapidly and intelligently*, local and global, information processing and service needs. Rapid and intelligent information exchanges are timely and avoid overload. In the NCO metrics framework, *Networking* consists of the *Network* (connectivity between nodes) and *Net-Ready Nodes* (force entities capable of sharing information and collaborating with others). Hence, networking refers to the extent of *interconnection* among *force entities*. The *Quality of Networking* directly depends on the nodes comprising the network, where the "nodes" are all the force entities capable of sharing information and collaborating with others.

Degree of networking consists of three attributes that describe the network. The first attribute, *reach*, addresses the degree to which force entities can interact. This starts with physical connectivity, and extends to include basic interoperability issues that enable content to move among entities. *Quality of service* focuses on the extent of connectivity. This includes the type of connection; voice or text data to full video conferencing capabilities. *Network Assurance* addresses the confidence one can reasonably have that force entities will have good connectivity. This includes the security, privacy, and integrity of the network and its contents.

The NCO Conceptual Framework begins by defining some key goals for the network and establishing a set of quantitative metrics that define the extent to which the goals are being

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[18] Provan, Keith G. & H. Brinton Milward. Do Networks Really Work? A Framework for Evaluating Public-Sector Organizational Networks. Pu*blic Administration Review*. July/ August 2001. Vol. 61. No. 4: pgs 414-423.
[19] http://searchnetworking.techtarget.com/sDefinition/0,,sid7_gci212644,00.html

achieved. The metrics are applied to the network to determine past and present levels of goal attainment and incremental changes in the network. Figure 4-5 below illustrates networking attributes and metrics.

## Degree of Networking

| Attribute | Metrics |
|---|---|
| Reach | Percent of nodes that can communicate in desired access modes, information formats, and applications |
| Quality of Service | Vector of performance metrics, including average bandwidth provided (available and bottleneck), packet delay, delay jitter, and data loss |
| Network Assurance | Categorical rating from "highly secure" to "not secure" (estimated from assessment of network's installed security software, hardware, and usage policies) |

*Figure 4-5. Degree of Networking Metrics*

The Degree of Networking measure is the extent to which force entities are interconnected, or capable of being interconnected. Another way to view this is how well the following goals are being met:

- Make information available on a network that people depend on and trust;
- Populate the network with new, dynamic sources of information to defeat the enemy; and
- Deny the enemy information advantages and exploit weakness to support Network Centric Warfare and the transformation of DoD business processes.[20]

### *4.2.3 Information*

Network Centric Operations postulates that effective networking leads to increased information sharing and ultimately to improved force effectiveness. Networking involves much more than the physical communication links between people and information systems that they use. Information systems in NCO must produce coherent information that can be transformed into awareness and then understanding. Because information exists in a dynamic environment, information systems must have the ability to adjust quickly to changing requirements. In short, information systems must produce information that is both cohesive and flexible.

[20] http://www.defenselink.mil/nii/homepage.html

Information is stimulus that has meaning in some context for its receiver. When information is entered into and stored on a network or computer, it is generally referred to as data. After some processing, data can again be perceived as information. The metrics framework evaluates three different types of information: organic, individual, and shared information.

Joint Publication 1-02 defines "organic" as being assigned to and forming an essential part of a military organization.[21] Organic information is information that is "derived" from the unit, community, or military organization. In other words, organic information is information derived from or gathered by an entity that is not shared and is unavailable to the network. For the most part, organic information remains local to the entity.

The attributes for organic information are located in Figure 4-6. They include Correctness, Consistency, Currency, and Precision and have a long history of applicability in the evaluation of command center performance that predates the origin of the NCO Conceptual Framework. The bottom half of the graphic lists specific fitness-for-use measures. These are Completeness, Accuracy, Relevance, and Timeliness. These two sets of measures are directly related. For example, correctness of a perceived enemy unit's headquarters location can be measured as an error in meters or kilometers, accompanied by some clarification concerning the specific rules for identifying location. Accuracy is also measured in meters, but is supplemented by some requirement that is associated with the sufficiency for use of the information. For instance, a 5km error in location is probably sufficient for determining general direction of unit movement over time in support of operational decisionmaking; it is deficient for purposes of supporting targeting activities.

## Quality of Organic Information

| Attribute | Definition |
|---|---|
| Objective Measures | Measures quality in reference to criteria that are independent of the situation |
| Correctness | Extent to which information is consistent with ground truth |
| Consistency | Extent to which information is consistent with prior information |
| Currency | Age of information |
| Precision | Level of measurement detail of information item |
| | |
| Fitness for Use Measures | Measures quality in reference to criteria that are determined by the situation |
| Completeness | Extent to which information relevant to ground truth is collected |
| Accuracy | Appropriateness of precision of information for a particular use |
| Relevance | Proportion of information collected that is related to task at hand |
| Timeliness | Extent to which currency of information is suitable to its use |

*Figure 4-6. Quality of Organic Information*

[21]Department of Defense, *Dictionary of Military and Associated Terms: Joint Publication 1-02*, 12 April 2001: pg 391.

UAIW speaks of networked forces in which entities will be net-ready to connect, with the presumption that they will increasingly depend upon non-organic information for their preferred mode of operations. Battlespace entities will not only receive information, but will be suppliers of information as well. Hierarchical flows of information will be streamlined, and peer-to-peer flows greatly increased.[22]

Individual Information is the first form of non-organic information that entities encounter. *Individual Information* refers to all the information available or presented to an entity. Individual Information provides the basis for awareness and understanding. It differs from Organic Information, because it also includes information that has been distributed over a network and obtained through some interaction. The attributes for Quality of Individual Information are also present in Shared Information see (Figure 4.8).

*Information Shareability* refers to a network's ability to accept, index, and transmit particular pieces of information, including data elements, data files, and streams of information quickly and accurately. Information Shareability is only concerned with whether or not it is easy to make data or information available to the network, and whether data and information can be found by force entities. It only considers whether or not what is submitted to the network is indexed correctly, stored without degradation, transmitted accurately and on demand, and presented to the receiver in a manner equivalent to what was initially submitted. The degree of Information Shareability is influenced by the physical properties of the network, including the transmission speed, accuracy, and the support for posting and retrieving different types of information. Figure 4.7 lists the attributes of Information Shareability.

## Degree of Information "Shareability"

| Attribute | Definition |
|---|---|
| Quantity of Posted Information | Extent to which collected information is posted |
| Quantity of Retrievable Information | Proportion of nodes that can retrieve various sets of information. Determined by the following:<br>•Awareness of Information: Degree to which the existence of the information is advertised to force member<br>•Access to Information: Degree to which access to information is controlled<br>• Meta-data of Information: Degree to which information has labels describing what it is and how it may be used (facilitates indexing and searching) |
| Ease of Use | Degree to which presentation of information facilitates desired use |

[22] *Understanding Information Age Warfare*: pg 295.

*Figure 4-7. Degree of Information Shareability*

*Shared Information* is information that is derived from the network. Note that the attributes for shared information are similar to the attributes for Individual Information with one exception: the concept of extent. This attribute measures the proportion of information that is held in common across force entities. Figure 4.8 below lists the attributes of both Individual and Shared Information. The Degree of Shared Information captures both the quality of the Shared Information, and the extent to which information is shared, while only the quality of the information is assessed for Individual Information and Organic Information.

## Degree of Shared Information

| Attribute | Definition |
|---|---|
| Objective Measures | Measures quality in reference to criteria that are independent of the situation |
| Extent | Proportion of information in common across force entities, within and across communities of interest (CoI)<br>Proportion of force entities that share information item |
| Correctness | Extent to which shared information is consistent with ground truth |
| Consistency | Extent to which shared information is consistent within and across CoI |
| Currency | Age of shared information |
| Precision | Level of measurement detail of shared information item |
| | |
| Quality | Measures quality in reference to criteria that are determined by the situation |
| Completeness | Extent to which shared information relevant to ground truth is obtained |
| Accuracy | Appropriateness of precision of shared information for a particular use |
| Relevance | Proportion of shared information retrieved that is related to task at hand |
| Timeliness | Extent to which currency of shared information is suitable to its use |

*Figure 4-8. Degree of Shared Information*

Together, Networking and Information form the center of Network Centric Operations. The extent to which entities are networked (quality of networking) along with their ability to rapidly and intelligently share information (quality and degree of information sharing) and utilize their organic capabilities (including organic information) are critical in determining overall effectiveness. Vice Adm. (ret.) Arthur K. Cebrowski asserted that a "lessons learned" in Iraq is that “good sensors networked with good intelligence and disseminated through a robust networking system accelerate combat on an order not seen before.”[23]

[23] David Hughes. Networking, Swarming and Warfighting. *Aviation Week & Space Technology*, September 29, 2003: pg 48. http://www.oft.osd.mil/library/library_files/article_246_Aviation%20Wee1.doc/

## 4.3 Sensemaking: Awareness, Understanding, and Decisionmaking

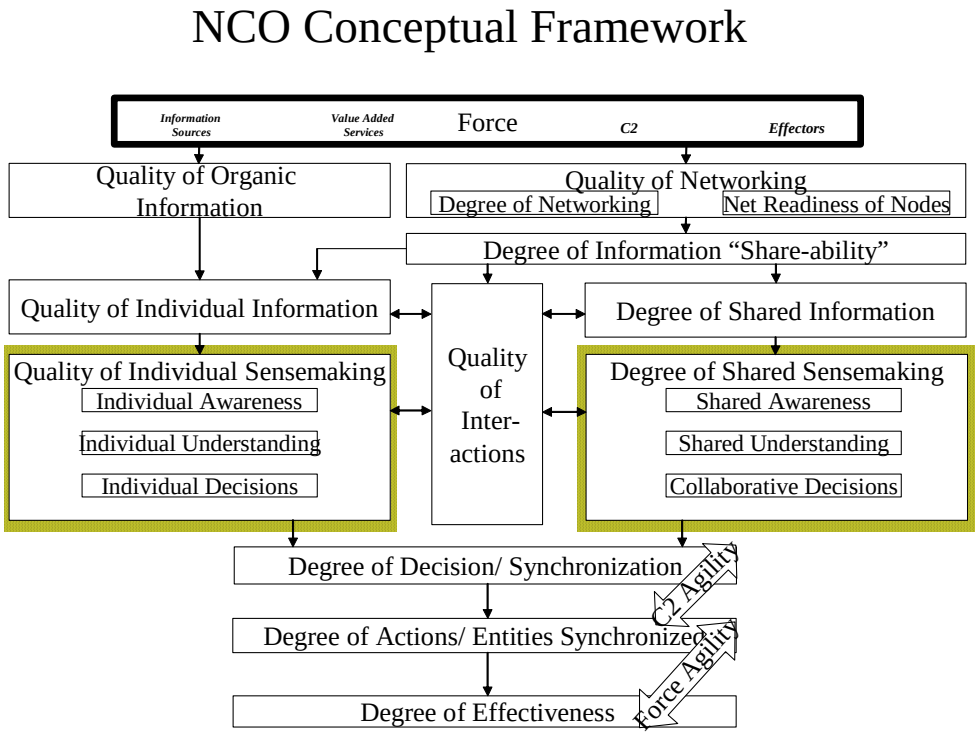


*Figure 4-8. The NCO Conceptual Framework*

As depicted within the NCO Conceptual Framework, sensemaking addresses those activities carried out at both the individual and collaborative level to (1) "make sense" of the information available in the context of experience/expertise, (2) draw from this information specific implications regarding potential threats and opportunities that require responsive action, and (3) organize these inferences into actionable knowledge that can frame key decisions. While moving from individual sensemaking to shared sensemaking involves interactions among different personnel and elements of the C2 system, this aspect of the process is addressed separately within the NCO CF in the "Quality of Interactions" top level concept (see section 4.4 below).

Sensemaking provides the link between the information domain depicted within the NCO framework and the physical domain in which action takes place. Sensemaking is largely a cognitive activity, i.e. it takes place in the minds of individuals, not computers—that is strongly influenced by social networks and social interactions at the collaborative level. This is why we refer to sensemaking as a "sociocognitive activity."

Sensemaking evolved as a concept from the earlier OODA loop depicted in traditional models of C4ISR. In this context, sensemaking most accurately corresponds to the "orient" step in the OODA loop model. However, as thinking has progressed regarding the OODA loop and its application to Information Age warfare, researchers have begun to demand a richer set of constructs to describe the process of turning data and information into actionable knowledge and operational decisions. Thus, in the book, *Understanding Information Age Warfare*, the "orient"

step of the OODA loop model was expanded to reflect a hierarchical process that included monitoring, awareness, understanding, sensemaking, command intent, battlespace management, and synchronization. These definitions have largely remained in later NCO publications.

Available research from the fields of naturalistic decisionmaking, management science, and complexity theory suggest that the conceptualization of awareness, understanding, decisionmaking, and so forth, should be merged into more of a single integrated cognitive process model. As our conceptualization of these processes evolve so also should the corresponding design and development of C4ISR systems supporting this cognitive process. The book, *Understanding Information Age Warfare*, depicted this idea in a series of charts shown here in Figure 4-9. The traditional model of C4ISR shows sensemaking largely separated from monitoring and awareness on the one hand, and from battlespace management on the other hand. As we move into the future, these processes are seen to merge into a nearly single integrated process that extends across the cognitive domain.

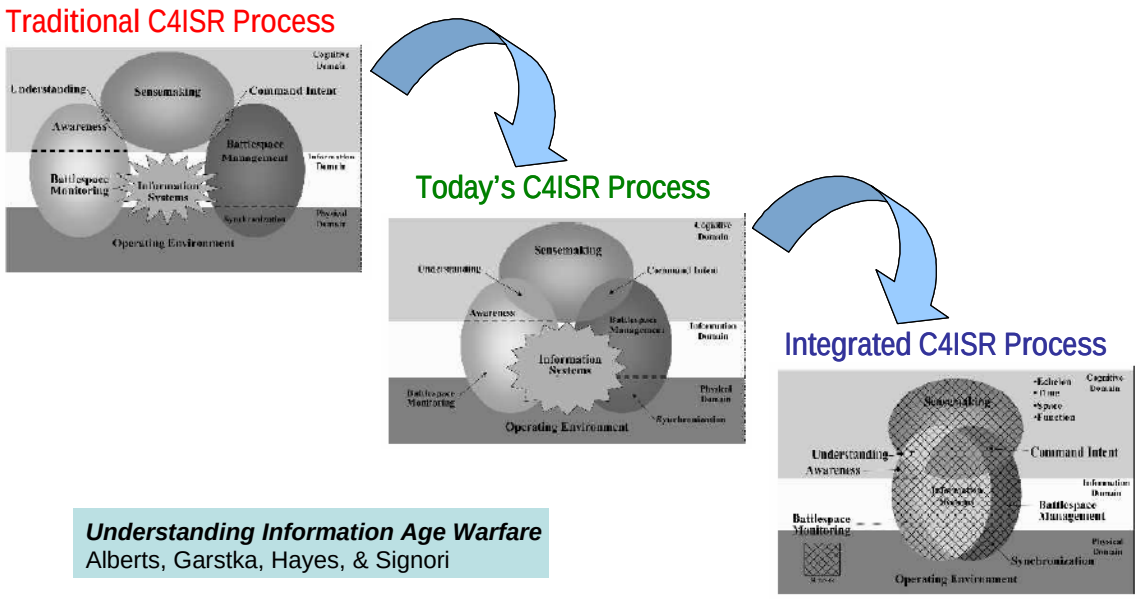


*Figure 4-9. Evolution of Process Models*

The concepts of awareness, understanding, and decisions are briefly defined below. **Awareness** is a process state existing in the cognitive domain. That is, it takes place in the minds of key leaders and their supporting battlestaffs, not in computers. Awareness is achieved through a complex interaction of available information, e.g. common operational picture, with prior knowledge and beliefs representing the experience and expertise of the battlestaff. Awareness relates to the operational situation as it currently is or was in the past. By contrast, **understanding** is defined as the process state of drawing inferences about possible consequences of the operational situation. It is based on the ability of the battlestaff—acting individually and collaboratively—to predict possible future patterns of the battlespace. That is, whereas awareness deals with the battlespace as it was or is, understanding deals with the battlespace as it is becoming. Interpreting these patterns—spatially, functionally, temporally—in the context of the goals/objectives, constraints, and planned courses of action envisioned for the operation, the

battlestaff begins to identify potential threats and opportunities that demand a responsive change or decision from the command authorities.

**Decisions** involve volition and choices about what is to be done to ensure that the mission is on a course that will achieve the intended goals/objectives. But notice decisions only take place within the "decision space" defined by the battlestaff's understanding. Hence, in the sensemaking model, understanding is seen to be the key step in the process, whereas decisions are seen as simply the culminating ratification of the mental activities that produced understanding. However, decisions involve something beyond merely understanding: they reflect commitment of the military organization to action.

While good decisions are generally based upon good understanding, this is not always the case. In fact, some decisions are forced or initiated by events within the battlespace—with understanding being developed in a post hoc manner. Likewise, awareness can be influenced by understanding—i.e. attention to particular details of the battlespace might be triggered by adopting a specific set of hypotheses as to what an adversary might be attempting. The point here is that the processes of awareness, understanding, and decisions do not always flow in one direction, but, rather, can unfold in a very interactive, emergent manner. Nevertheless, however, these processes represent different aspects of sensemaking that can be isolated, measured, and assessed.

The importance of developing a correct understanding of a situation is supported by empirical research evidence that correlates quality of understanding with the quality of subsequent decisions that emerge from the C2 process.[24] This evidence cuts across the tactical and operational levels of command. While it is recognized that understanding reflects a great deal of subjectivity—i.e. it is based on interpretations and hypotheses developed from prior experience—it is possible to define "correctness" or "quality" in terms of how experienced subject matter experts might size up a given situation. Thus, in terms of measurement and assessment, quality of understanding can be calibrated in terms of senior officers who advise or critique a particular operation or exercise. Increasingly, "ground truth" can be obtained via "instrumented reality" exercises and simulations, making assessment of correctness more reliable.[25]

Sensemaking is both an individual process and a collective process. At the individual level, sensemaking involves the mental relating of situation understanding with action. That is, it involves building a mental model that hypothesizes how a situation might evolve over time, what threats and opportunities for action are likely to emerge from this evolution, what potential actions can be taken in response, what are the projected outcomes of those responses, and what

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[24] *Enhancements to Army Command and Control Evaluation System (ACCES) Draft Technical Report,* October 1990 finds that Quality of Situational Awareness is the best predictor of Command and Control Effectiveness (C2), Force Effectiveness, and Military Plan Quality. Also during the 1990s, Air-to-Air Mission: Offensive and Defensive Counter using Voice + Data Link Improved Situational Awareness which led to a 150% improvement in operations (see *Understanding Information Age Warfare:* pg 252).

[25] For example, the Future Combat System C2 Prototype Experimentation conducted by the Army's CECOM and DARPA collects extensive data on ground truth, making it relatively simple to compare the commander's articulated understanding of the battle space with ground truth.

cultural values drive the choice of future action. This part of the process involves three interrelated activities: (1) generating alternative response actions to control the situation; (2) identifying the objectives, constraints, and factors that influence the feasibility and desirability of each alternative, and (3) conducting an assessment of these choices. As noted earlier, these three processes are often integrated into a single mental activity and can be either (1) the subject of a very formal staff process or (2) as simple as one officer examining a situation and making up his mind.

At the collective level, sensemaking is represented as a collaborative process involving different functional perspectives and possible stakeholder interests. Military operations involve the coordination of many different functional elements—each of which will be "seeing" specific emerging threats and opportunities from their own perspective. Different stakeholder interests might also exist across organizational boundaries within a coalition. In order to achieve operational synchronization, these perspectives must be melded into a common problem framework where the different aspects of the operation are adjudicated and integrated into a single vision. Thus, shared sensemaking becomes a crucial part of the C4ISR process.

The fact that sensemaking occurs at a collective level implies the need to add a fourth domain to the NCO framework: the social domain where different force entities interact. Adding the social domain to the NCO framework brings with it a new set of factors and issues. Whether or not these different entities can effectively exchange information, reconcile perspectives, and achieve a common understanding and vision of the operation depends not only on the technical means of communicating and collaborating, but also on various social factors that govern this collective process. Shared sensemaking involves human interaction and collaboration across different communities of expertise and cultural boundaries. Commonality of training, doctrine, and procedures affect the process of shared sensemaking, as do the factors of interpersonal familiarity and trust and overall organizational leadership.

We now move into a discussion of the actual NCO framework section on sensemaking, as depicted in the next set of slides that summarize the measures and metrics developed to date. Figure 4-10 defines the various attributes of individual awareness. As seen here, these attributes include both objective measures (measures of quality that are independent of the operational situation) and fitness of use measures (measures that are contextually defined in terms of the demands of a specific situation).

Highlighted are two examples that illustrate the general approach taken for observing and assessing attributes of individual awareness. At the top of the table, we see that awareness is objectively assessed in terms of correctness, consistency, currency, and precision. "Currency," for example, reflects the time lag of awareness of an individual. This type of measure is considered objective in the sense that it is independent of a particular decision event or emergent threat/opportunity. Figure 4-11 represents how it might be calculated.

| Attribute | Metrics |
|---|---|
| Objective Measures | Measures quality in reference to criteria that are independent of the situation |
| Correctness | Correspondence with ground truthcorrelation coefficient (0= no convergence, 1=full convergence between individuals awareness and ground truth) |
| Consistency | Degree of 'deviation' from awareness gained from previous time period |
| Currency | Time lag of awareness |
| Precision | Level of granularity ofawareness |
| | |
| Fitness for Use Measures | Measures quality in reference to criteria that are determined by the situation |
| Completeness | Percentage of ground truth picture included in awareness |
| Accuracy | Degree to which precision matches what is needed (0=no match, 10=high degree of matching between precision level needed and available) |
| Relevance | Proportion of awareness that is related to task at hand |
| Timeliness | Degree to which currency matches what is needed (0=no match, 10=high degree of matching between currency level needed and available) |
| Uncertainty | Confidence level (0% =uncertain, 100%= certain) or confidence interval (95%, 90%, etc.) of awareness |

*Figure 4-10. Individual Awareness: Attributes and Metrics*

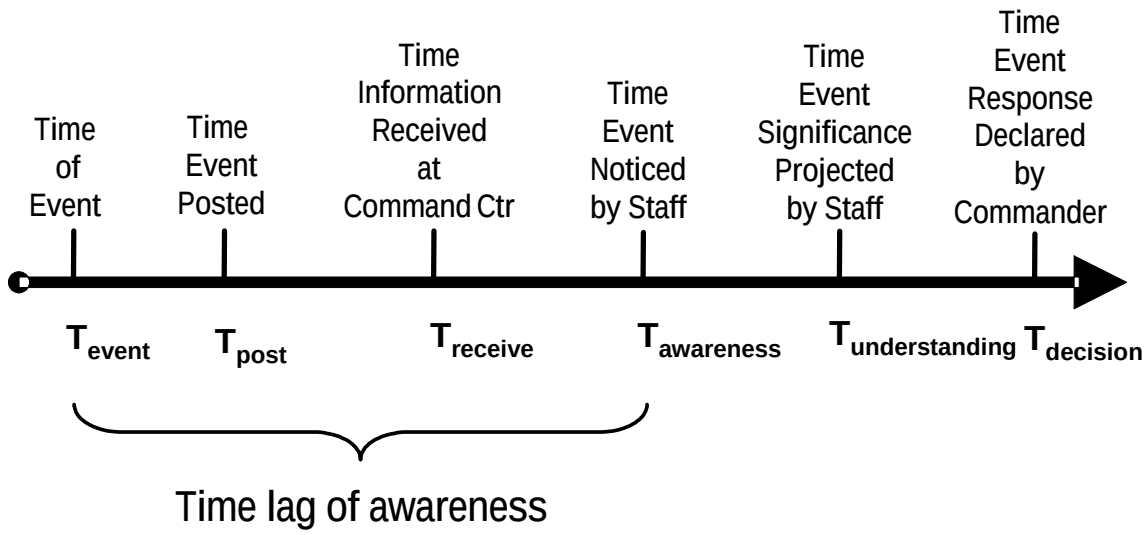


*Figure 4-11. Currency of Awareness*

By contrast, moving to the bottom of the table, we see that "timeliness" is a fitness-for-use measure. That is, "timeliness" reflects the degree to which the currency of the information comprising awareness suitably supports the use of this awareness for building understanding and making decisions. In other words, "timeliness" expresses the degree to which the currency of awareness provides an adequate window of decisionmaking opportunity for the battlestaff.

With metrics, the goal is to define each attribute in terms that support quantitative measurement and comparison between different cases. For example, it might be possible in some situations to measure the degree of statistical correlation of awareness with ground truth that exists across a relevant set of objects or features within the battlespace.

As a fitness-for-use measure, timeliness will involve the judgment of subject matter experts to assess the degree to which the timeliness of individual awareness meets the requirements of a specific operational situation. Such judgments can be quantitatively captured using a metric approach based on Likert scales.

By comparison, when we move to an assessment of shared awareness, our focus is now placed on a comparison of perceptions across different individuals—or, in some cases, between different functional staff elements or between different organizations. Thus, to the set of objective measures we add the measure of "extent." Figure 4-12 provides a list of all the attributes and their associated metrics for shared awareness.

| Attribute | Metrics |
|---|---|
| **Objective Measures** | **Measures quality in reference to criteria that are independent of the situation** |
| **Extent** | **Percentage of awareness elements (relevant objects and events) held in common within and across each Community of Interest** |
| **Correctness** | **Correspondence with ground truth-correlation coefficient (0= no convergence, 1=full convergence between individual's awareness and ground truth)** |
| **Consistency** | **Degree of 'deviation' from awareness gained from previous time period** |
| **Currency** | **Time lag of awareness** |
| **Precision** | **Level of granularity of awareness** |
| | |
| **Fitness for Use Measures** | **Measures quality in reference to criteria that are determined by the situation** |
| **Completeness** | **Percentage of ground truth picture included in awareness** |
| **Accuracy** | **Degree to which precision matches what is needed (0=no match, 10=high degree of matching between precision level needed and available)** |
| **Relevance** | **Proportion of awareness that is related to task at hand** |
| **Timeliness** | **Degree to which currency matches what is needed (0=no match, 10=high degree of matching between currency level needed and available)** |
| **Uncertainty** | **Confidence level (0% =uncertain, 100%= certain) or confidence interval (95%, 90%, etc.) of awareness** |

*Figure 4-12. Shared Awareness: Attributes and Metrics*

Here, extent is a measure used to reflect the degree to which different force elements develop and maintain a common awareness within and across specific communities of interest (sets of battlestaff elements and force entities involved in synchronizing specific aspects of the operation). As seen here, "extent" can be measured in two ways: (1) comparing the commonality of awareness across force entities and (2) assessing the proportion of awareness held in common across force entities.

Again, moving to the level of quantifiable metrics, we see that extent of shared awareness might be measured utilizing a measure such as Cronbach's alpha. Figure 4-13 presents an illustrative example of how this could be calculated.

| List of Key Battlespace Objects & Activities | C2 Node $N_1$ | $N_2$ | $N_3$ | $N_4$ | … | $N_i$ |
|---|---|---|---|---|---|---|
| $O_1$ | 1 | 1 | 1 | 0 | … | 1 |
| $O_2$ | 1 | 0 | 0 | 0 | … | 1 |
| $O_3$ | 0 | 1 | 1 | 1 | … | 1 |
| . | . | . | . | . | | . |
| . | . | . | . | . | | . |
| $O_j$ | 0 | 1 | 1 | 1 | … | 1 |
| $E_1$ | 1 | 0 | 1 | 0 | … | 0 |
| $E_2$ | 1 | 1 | 1 | 0 | … | 1 |
| $E_3$ | 1 | 1 | 0 | 0 | … | 0 |
| . | . | . | . | . | | . |
| . | . | . | . | . | | . |
| $E_k$ | 1 | 0 | 0 | 0 | … | 1 |

Cronbach's Alpha

$$\alpha = \left\{ \frac{i \cdot \bar{r}}{1 + (i-1) \cdot \bar{r}} \right\}$$

where $\bar{r}$ is the average intermode correlation among key objects and activities

*Figure 4-13. Extent of Shared Awareness*

For assessing individual understanding, the NCO framework employs a set of measures and metrics that are consistent with those used for assessing awareness (see Figure 4-14 below). However, given the increased complexity of understanding and its greater dependence upon personal experience and expertise, these measures and metrics will be interpreted differently from those used for assessing awareness.

| Attribute | Definition |
|---|---|
| **Objective Measures** | **Measures quality in reference to criteria that are independent of the situation** |
| **Correctness** | **Extent to which understanding is consistent with ground truth** |
| **Consistency** | **Extent to which understanding is internally consistent with prior understanding** |
| **Currency** | **Time lag of understanding** |
| **Precision** | **Level of granularity of understanding** |
| | |
| **Fitness for Use Measures** | **Measures quality in reference to criteria that are determined by the situation** |
| **Completeness** | **Extent to which relevant understanding is obtained** |
| **Accuracy** | **Appropriateness of precision of understanding for a particular use** |
| **Relevance** | **Proportion of understanding obtained by force member that is related to task at hand** |
| **Timeliness** | **Extent to which currency of understanding is suitable to its use** |
| **Uncertainty** | **Subjective assessment of confidence in understanding** |

*Figure 4-14. Individual Understanding: Attributes and Metrics*

Using again the example of "currency," Figure 4-15 below illustrates how it might be calculated for individual understandings.

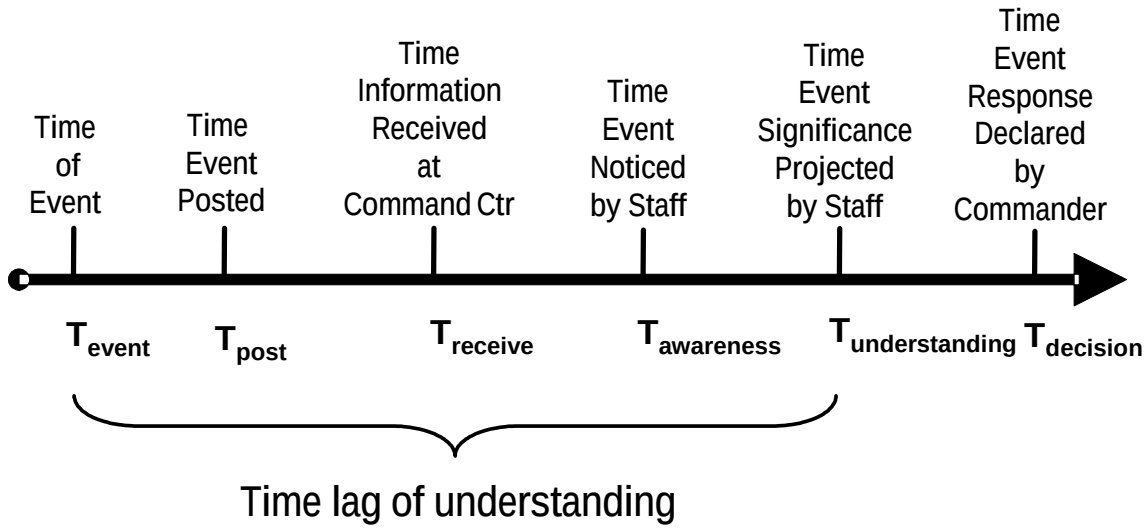


*Figure 4-15. Currency of Understanding*

A similar pattern of attribute measures is shown here for shared understanding. As with awareness, a measure defined as "extent" of shared understanding is added to the list of measures to reflect the degree to which a common understanding is held within and across specific Communities of Interest. See Figure 4-16 for a complete list of all attributes and metrics for shared understanding.

| Attribute | Definition |
|---|---|
| **Objective Measures** | **Measures quality in reference to criteria that are independent of the situation** |
| **Extent** | **Proportion of understanding in common across force entities, within and across Communities of Interest (COI)**<br>**Proportion of force entities that share a given understanding** |
| **Correctness** | **Extent to which shared understanding is consistent with ground truth** |
| **Consistency** | **Extent to which shared understanding is consistent within and across COI** |
| **Currency** | **Time lag of shared understanding** |
| **Precision** | **Level of granularity of shared understanding** |
| | |
| **Quality** | **Measures quality in reference to criteria that are determined by the situation** |
| **Completeness** | **Extent to which relevant shared understanding is obtained** |
| **Accuracy** | **Appropriateness of precision of shared understanding for a particular use** |
| **Relevance** | **Proportion of shared understanding that is related to task at hand** |
| **Timeliness** | **Extent to which currency of shared understanding is suitable to its use** |
| **Uncertainty** | **Subjective assessment of confidence in shared understanding** |

*Figure 4-16. Shared Decisions: Attributes and Metrics*

Finally, we come to the decision component of sensemaking. Figure 4-17 lists all attributes and metrics for individual decisionmaking.

| Attribute | Metrics |
|---|---|
| Objective Measures | Measures quality in reference to criteria that are independent of the situation |
| Consistency | Extent to which decisions are internally consistent with prior understanding and decisions |
| Currency | Time lag of decisions |
| Precision | Level of granularity of decisions |
| | |
| Fitness for Use Measures | Measures quality in reference to criteria that are determined by the situation |
| Appropriateness | Extent to which decisions are consistent with existing understanding, command intent and values |
| Completeness | Extent to which relevant decisions encompass the necessary:<br>•Depth: range of actions and contingencies included<br>•Breadth: range of force elements included<br>•Time: range of time horizons included |
| Accuracy | Appropriateness of precision of decisions for a particular use |
| Relevance | Proportion of decisions that are significant to task at hand |
| Timeliness | Extent to which currency of decision making is suitable to its use |
| Uncertainty | Subjective assessment of confidence in decisions |
| Risk Propensity | Extent of risk aversion |
| | |
| Mode of Decision Making | Type of decision making process utilized (naturalistic, dominated, min-max, expected utility) |

*Figure 4-17. Individual Understanding: Attributes*

Two examples illustrate the nature of assessment at this level. In the first example, we see that decision time can be measured both objectively and in terms of fitness-for-use. Objectively, we can measure the time lag of decisions—say, from when an adversary initiates a specific operation to when the C2 system formulates a specific response decision. Figure 4-18 represents the currency of decisionmaking.

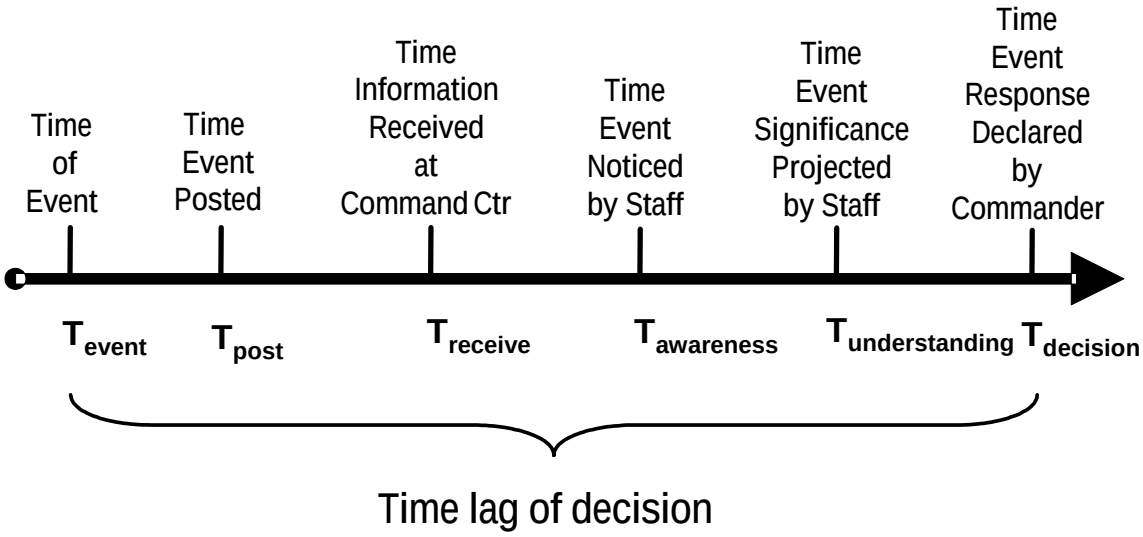


*Figure 4-18. Currency of Decisionmaking*

The second example highlights the measure of "appropriateness." Here, "appropriateness" reflects the degree to which individual decisions are consistent with (1) the existing understanding of the situation, (2) command intent, and (3) the values of the military organization. As with other measures of this degree of complexity and situational dependence, assessment of this measure would be based on senior subject matter expertise.

Following the same pattern of moving from individual awareness and understanding to shared awareness and understanding, we see that collaborative decisions involve the additional measure of "extent," defined here as the proportion of force entities effectively involved in reaching a collaborative decision (see Figure 4-19).

In addition, the definitions of other measures are expanded to reflect the shared nature of the process. Thus, for example, appropriateness of collaborative decisions is measured with respect to the degree it reflects shared understanding, command intent, and shared team or organizational values.

Finally, it is noted that the degree of synchronization of decisions across force elements is not addressed in this portion of the NCO framework. Synchronization, an important element of NCO, is addressed next as its own separate area of measurement and assessment.

| Attribute | Definition |
|---|---|
| Objective Measures | Measures quality in reference to criteria that are independent of the situation |
| Extent | Proportion of force entities that reach a collaborative decision |
| Consistency | Extent to which decisions are in agreement across force entities, within and across COI |
| Currency | Time lag of decisions |
| Precision | Level of granularity of decisions |
| | |
| Fitness for Use Measures | Measures quality in reference to criteria that are determined by the situation |
| Appropriateness | Extent to which decisions are consistent with existing shared understanding, command intent and shared team values |
| Completeness | Extent to which relevant decisions encompass the necessary:<br>•Depth: range of actions and contingencies included<br>•Breadth: range of force elements included<br>•Time: range of time horizons included |
| Accuracy | Appropriateness of precision of decisions for a particular use |
| Relevance | Proportion decisions that are important to the accomplishment of the task at hand |
| Timeliness | Extent to which currency of decision making is suitable to its use |
| Uncertainty | Inter-subjective assessment of confidence in decisions |
| Risk Propensity | Extent of risk aversion |
| | |
| Mode of Decision Making | Type of collaborative decision making structure utilized (authoritative decision making, consensus building, majority rule, etc.) |

*Figure 4-19. Collaborative Decisions: Attributes and Metrics*

## 4.4 Quality of Interactions

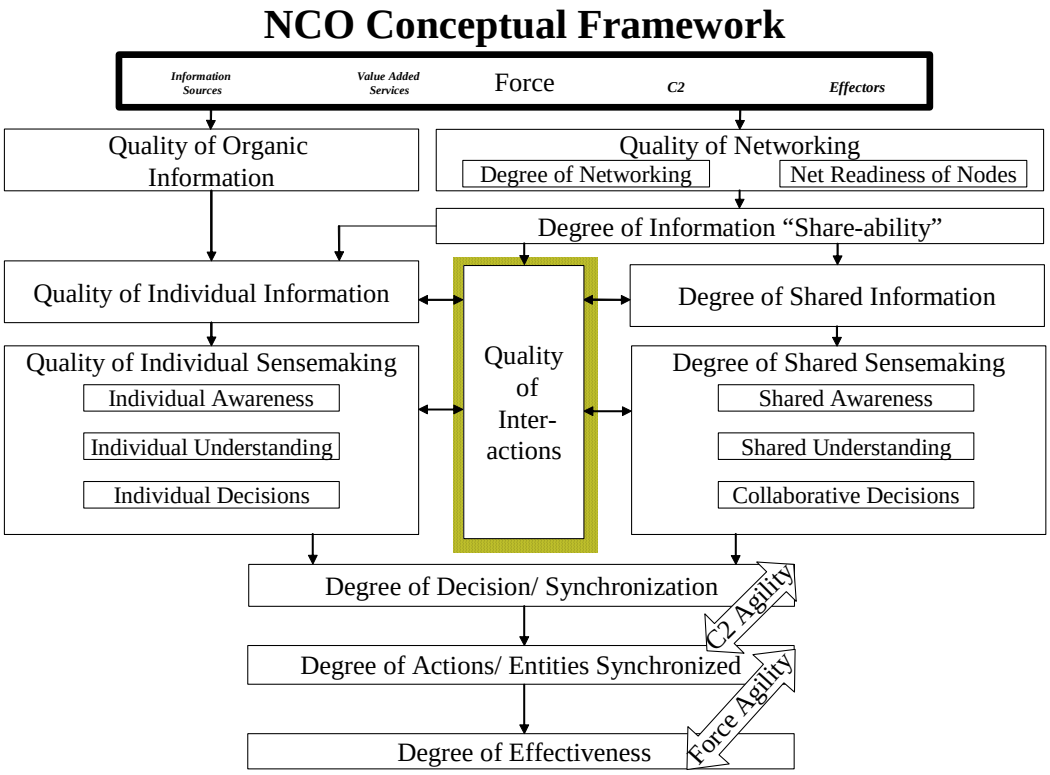


*Figure 4-20. The NCO Conceptual Framework*

### *4.4.1 Role of "Quality of Interactions" in the Conceptual Framework*

Interactions involve force entities actively sharing information, and developing awareness, understanding and/or making decisions (developing plans) in a collaborative fashion while working together toward a common purpose. The "Quality of Interactions" top-level concept bridges the gap between individual and shared information and sensemaking and cuts across the Information, Cognitive and Social Domains in the Conceptual Framework. The concept "Quality of Interactions" also includes "control variables" that impact performance and effectiveness. Importantly, it provides a means to measure the extent to which network-centric *processes* are being implemented. As Mission Capability Packages co-evolve, we expect that the characteristics and behaviors of individuals and organizations will reflect these changes. The attributes of Quality of Interaction are indicators of the key process elements that are likely to evolve as we move toward a network-centric force.

Depending on the context, the quality of interactions can be considered an independent variable or a dependent variable. As an independent (or explanatory) variable, it can impact or influence the values of Individual and/or Shared Sensemaking directly and the degree of decision/actions/entities synchronized and the degree of effectiveness indirectly. For instance, an experimental design may be established to explore how different modes of interaction (reflecting different MCPs) impact shared awareness and understanding. Holding constant all the other variables in the NCO Value Chain that precede Quality of Interactions in the Conceptual

Framework (like degree of networking), one could determine how different modes or types of collaboration impact decisionmaking.

As a dependent variable, researchers would primarily be interested in how net-centric technologies and practices impact the ways in which people interact and collaborate. Although mission effectiveness is always of interest and concern, it may be practical to limit an experiment and/or analysis to a subset of the NCO CF. Factors that impact the quality of interactions are information shareability, individual and shared information and sensemaking. The quality of networking has an indirect impact on quality of interactions. If we want to isolate the impact of NCO Value Chain Concepts, it is important to include control variables that capture exogenous characteristics of the interactions.

In many cases, the quality of interactions can be considered an intervening variable, that is, it is an intermediate factor that mediates the impact of net-centric technologies and practices on effectiveness. In such cases, if we wish to isolate the impact of NCO variables on high-level outcomes such as effectiveness, it is essential to include the control factors mentioned previously.

### *4.4.2 Models of Interaction*

The model of interactions presented in the Conceptual Framework represents efforts to integrate existing knowledge on teamwork, collaboration, and interaction in military and non-military contexts. It draws on and extends existing theories and research on team effectiveness, collaboration, and complex multiteam interactions. Three models of interactions are particularly relevant to the model developed here. The Team Effectiveness Model developed by Ed Salas, of the University of Central Florida, et al.; the Collaboration Effectiveness Model, developed by David Noble of EBR, which focuses on the factors that are necessary for successful collaboration; and the Multi-Team Effectiveness Model by John Mathieu of University of Connecticut, which provides insights into interactions that cut across individual organizations, echelons, services, function, etc. These interactions are best thought of as episodes of multiteam collaboration. This approach emphasizes the interdependencies of interactions over time and space. We discuss each of these models below.

The model of Team Effectiveness represented in Figure 4-21 was originally developed by Salas et al and has been widely adopted and adapted in the field of team effectiveness research. This model assumes that team effectiveness is a function of inputs (such as individual, team and task characteristics), and processes, such as communication and coordination. Outcomes are measured in terms of products of the collaborative process (meeting objectives/mission success), and are typically measured by the quantity and quality of the products and the efficiency and effectiveness of the process involved in producing those products.

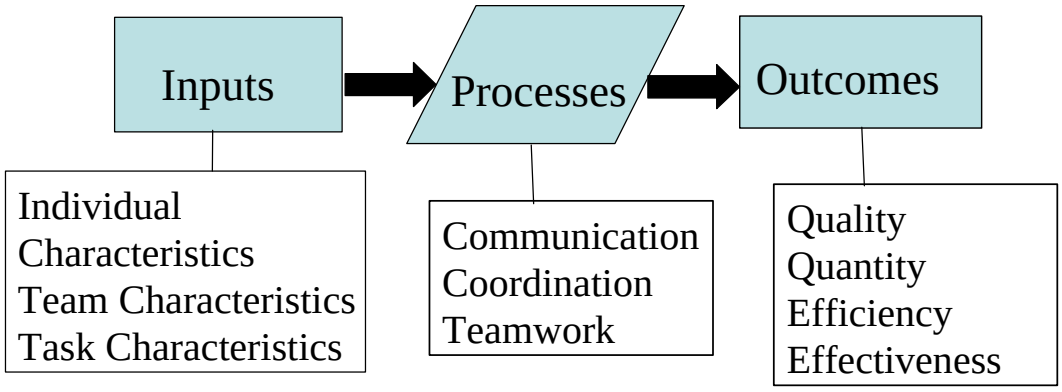


*Figure 4-21. Models of Interaction (1)*

David Noble, of EBR, has developed a Collaboration Effectiveness Model that focuses in detail on the specific knowledge processes and behaviors that facilitate successful collaboration. As indicated in Figure 4-22 below, this model explicitly ties collaboration to individual and shared sensemaking. Dr. Noble distinguishes among activities aimed at setting up and adjusting the team, group problem solving activities, and activities focused on synchronization and actions. There are multiple feedback loops between interactions and sensemaking, illustrating the complex dependencies among these activities.

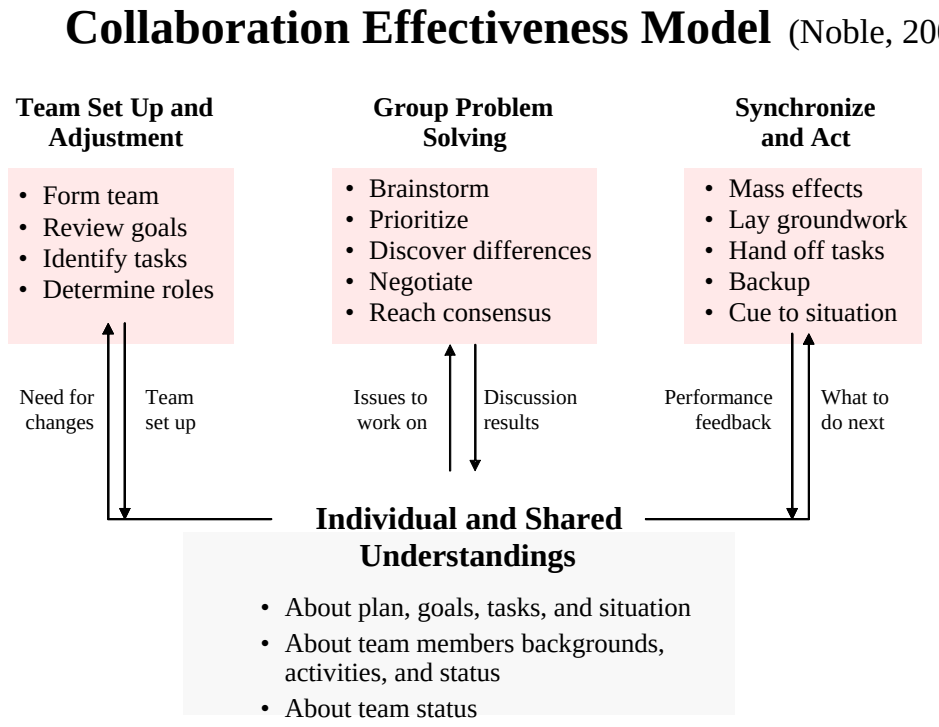


*Figure 4-22. Models of Interaction (2)*

Recent work by John Mathieu et al provides a useful extension of the Input-Process-Output model of team effectiveness that illustrates key insights relevant to Information Age interactions. The authors argue that most activities of interest involve multiple "teams" that cut across echelons, organizations, countries, etc., and time and space. They extend the IPO model to

include multiple tasks, competing goal hierarchies and complex dependencies across Inputs, Processes, and Outcomes. The distinguishing characteristic of Multi-Teams is that they typically are from different organizations, echelons, etc., and they have different proximate goals, identities, and practices, but they share a common distal goal (command intent). They also exhibit input, process, and outcome interdependencies. Figure 4-23 illustrates a stylized Scenario in which multiple teams across services and coalition partners operate to achieve tasks that have complex dependencies across time and space.

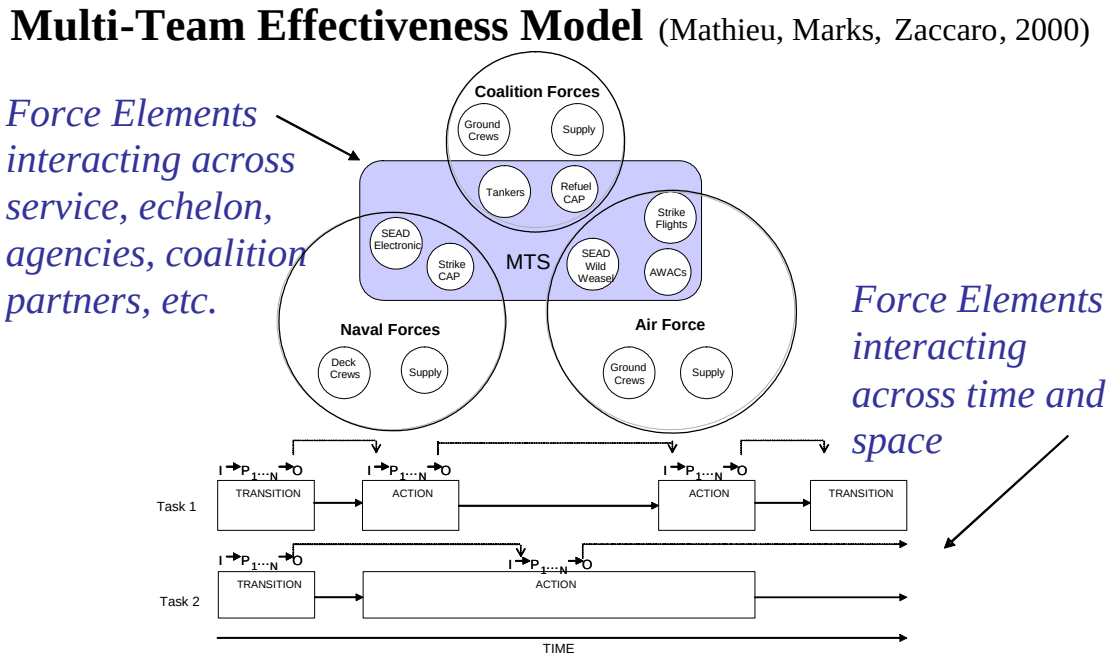


*Figure 4-23. Models of Interaction (3)*

### *4.4.3 NCO Conceptual Framework Model of Interactions*

Building on these three models and other theory and research, the NCO CF model of interactions identifies the key inputs, processes and outcomes of interactions. At the outcome level, we diverge from the models that measure effects in terms of the products of interaction and instead focus on the quality of interactions themselves, and not the results. We do this because the accomplishment of tasks/missions is measured elsewhere in the conceptual framework. Instead, we focus on the depth, breadth, intensity and agility of interactions. We also diverge from the Team Effectiveness Model by using the term "organization" rather than "team." Building on the multiteam work, we assume that activities of interest can range from traditional teams to systems of multiteams, to full fledged organizations. We designate all of these interactions as "organizations."

Individual and Organizational characteristics are highlighted as important factors that impact the quality of interactions and are equivalent to the INPUTS in the previous models. Organizational and Individual Behaviors also impact the quality of interactions and are equivalent to the PROCESSES of previous models. In the context of the NCO CF, sometimes these inputs and processes can be manipulated, i.e. aspects of MCPs that can be systematically varied; and

sometimes they can be considered to be “control variables” in that they are outside of the theory of NCO but nonetheless can be important explanatory factors of mission effectiveness.

Figure 4-24 is a representation of the model of interactions developed in the Conceptual Framework

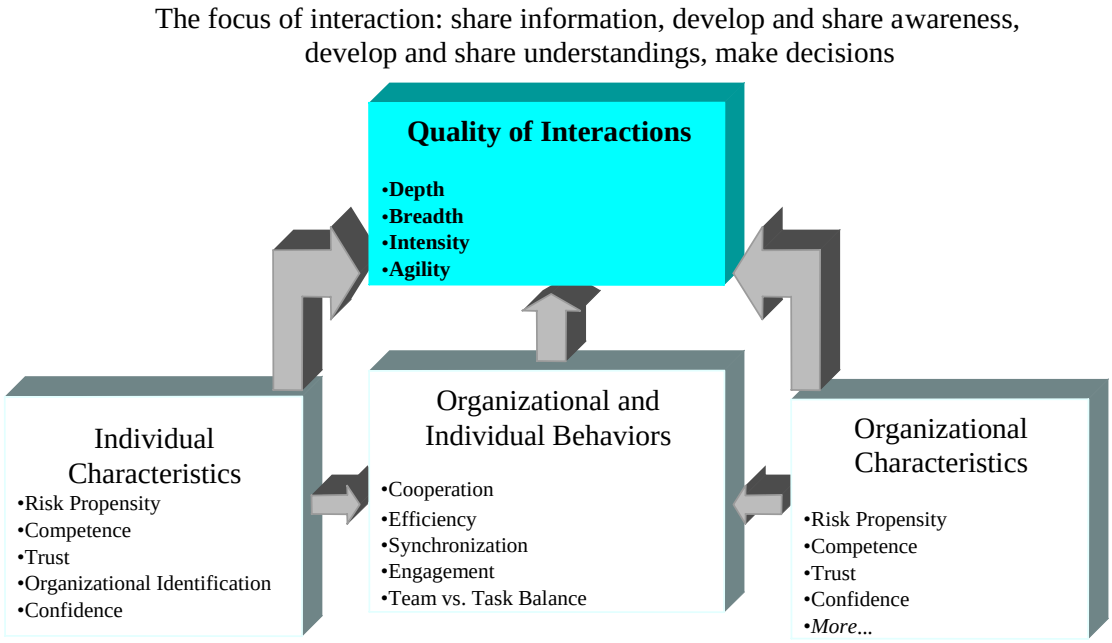


*Figure 4-24. Quality of Interactions: Attributes and Exogenous Variables*

. There are four “top-level” attributes of interactions:

- **Depth** – Measures that describe the nature of the substance of interactions
- **Breadth** - Measures that describe the force entities that interact
- **Intensity** – Measures that describe the pace and completeness of interactions
- **Agility** – Measures that that describe the Robustness, Resilience, Flexibility, Responsiveness, Innovativeness, and Adaptability of interactions

Each of the four primary attributes of Quality of Interactions is composed of sub-attributes. Figure 4-25 presents each of the four top level attributes and all of the associated sub-attributes.

| Attribute | Definition |
|---|---|
| **Depth** | Measures that describe the nature of the substance of interactions |
| Quantity | The quantity of information, awareness, understandings, and/or decisions that are the focus of interactions |
| Quality | The quality of information, awareness, understandings, and/or decisions that are the focus of the interactions |
| **Breadth** | Measures that describe the force entities that interact |
| Reach | The number of members that participate in the interactions |
| Selectivity | The ability to reach a selected subset |
| **Intensity** | Measures that describe the pace and completeness of interactions |
| Continuity | The persistence of the exchange among members (continuous to episodic) |
| Synchronicity | Type of interaction: synchronous or asynchronous in time and space |
| Mode | Degree to which all senses are involved (ranges from face to face with data + voice to voice or data only) |
| Latency | The time lag of interactions |
| **Agility** | Robustness, Resilience, Flexibility, Responsiveness, Innovativeness, and Adaptability |

*Figure 4-25. Quality of Interactions: Top Level Attributes*

We will focus on the quantity of interactions to illustrate why this is a useful measure of overall quality of interactions. If we consider the Air-to-Air Case Study, it was hypothesized that one explanation for the dramatic increase in effectiveness was that pilots with Link 16 plus Voice communications used their time differently than pilots with Voice Only. Figure 4-26 illustrates this. It illustrates how the quantity of interactions and the nature of those interactions may be impacted by network centric technologies and practices.

***Hypotheses:***

***I. Information sharing via Voice + Link 16 leads to less time necessary to gather critical information, which results in more time available for pilots and crew to interact sharing awareness and understandings***

***II. Information sharing via Voice + Link 16 leads to less time necessary for wingman to gather and monitor critical information, which results in more time available for wingman to interact sharing awareness and understandings***

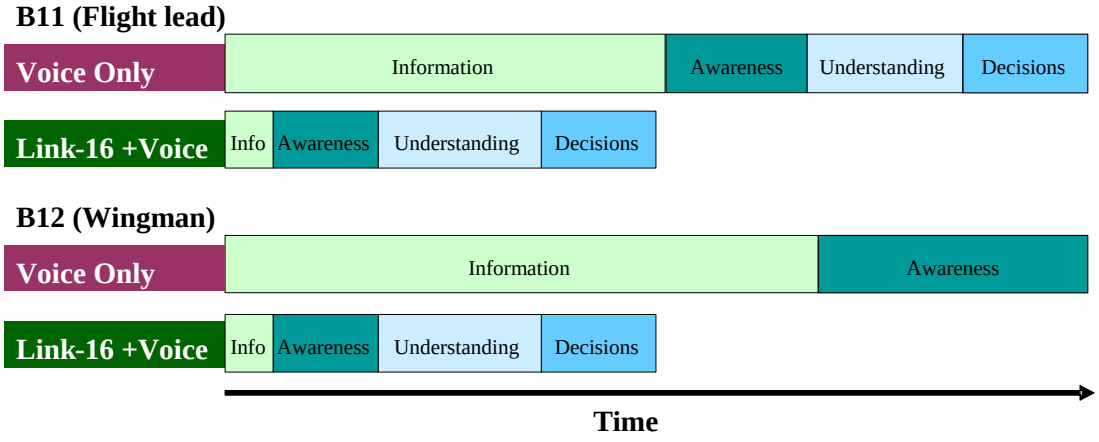


*Figure 4-26. Quality of Interactions*

Hypotheses I states that with Link 16 plus Voice communications, pilots are spending much less time interacting with the crew to gather information. Instead, the focus of interactions shifts away from exchanging information to building and sharing awareness and understandings. Hypothesis II extends this reasoning to the wingman. Instead of focusing on information gathering, monitoring and reporting, the wingman can spend much more time sharing awareness and understandings.

Although this is hypothetical, it is quantifiable with the NCO CF attributes and metrics. In order to gather data necessary to test this hypothesis, we could use cockpit recordings and with qualified coders determine the nature of the interactions among and between crew members.

As stated above, a basic assumption is that characteristics and behaviors of individuals and organizations have an impact on the likelihood of successful interactions (that is, they impact the quality of interactions obtainable). These factors are discussed next.

### *4.4.4 Individual Characteristics*

The individual characteristics that we focus on are risk propensity, competency, trust, organizational identification, and confidence (see Figure 4-27 below). We will focus on one of these attributes, the Organizational Identity of the individual, to illustrate the approach. Research on identification indicates that interactions in which the individuals involved identify with the group (or collective), that is they share important goals and values, are more likely to be of a higher quality both in terms of the subjective assessments of the participants and in terms of the outcomes (or products) of the interactions.[26] Within a military context, this relates to loyalty and commitment to command intent. In the Air-to-Air example, because these were training missions we can assume that organizational identification did not vary between the voice only crews and the Link 16 crews. However, if our case study involves multiple teams across services, agencies, coalitions, etc., we would expect that people's identification with the goals and norms of the organization would vary dramatically. In fact, in these cases, we would expect competing goals and values. The Conceptual Framework provides the means to measure the extent to which this occurs and provides a mechanism to determine the impact this has on effectiveness.

[26] Jehn, K., Chadwick, C., and Thatcher, S.M.B. (1997). "To Agree or Not to Agree: The Effects of Value Congruence, Individual Demographic Dissimilarity, and Conflict on Group Outcomes." International Journal of Conflict Management, 8, 287-305.

| Attributes | Definition |
|---|---|
| **Risk Propensity** | Extent of risk aversion |
| **Competence** | Level of knowledge, skills, abilities, and attitudes (KSAAs) |
| **Trust** | Extent to which individual is willing to rely on other members |
| **Organizational Identification** | Extent to which individual's identities align with organizational identities |
| **Confidence** | Degree of individual's expectation that other members are reliable |

*Figure 4-27. Exogenous Variables: Individual Characteristics*

### *4.4.5 Team/Organization Characteristics*

In addition to the characteristics of the individual, the characteristics of the organization (or team or collection of teams) matters as well. We have identified eleven attributes that influence mission/objective success: risk propensity, competence, trust, confidence, size, hardness, diversity, permanence, autonomy, structure and interdependence (see Figure 4-28 below).

| Attributes | Definitions |
|---|---|
| Risk Propensity | Extent of risk aversion |
| Competence | Distribution of members knowledge, skills, abilities and attitudes (KSAAs) |
| Trust | Extent to which members are willing to rely on one another |
| Confidence | Extent to which members have expectations of the reliability of the organization |
| Size | Number of team members involved |
| Hardness | Degree to which team members have interacted in the past on the same task |
| Diversity | Degree to which team members are heterogeneous or homogeneous across exogenous variables: experience, age, gender, etc. |
| Permanence | Expected duration of organization |
| Autonomy | Extent to which organization is externally or self directed |
| Structure | Distribution of peer and authority relationships<br>• Layers of authority<br>• Functional Differentiation<br>• Connectedness within and across layers<br>• Directness of connections |
| Interdependence | Extent to which members depend on one another for resources (materials, KSAAs, etc.) |

*Figure 4-28. Exogenous Variables: Organizational Characteristics*

Interdependence is an illustrative attribute. It is defined to be the extent to which members depend on one another for resources. In the Air-to-Air example, crew members could meet their resource needs independently. They relied on one another and the AWACs for information but their actions did not require coordination of inputs and processes. If we take the stylized SEAD scenario presented earlier, however, we can see that in some cases there is a high degree of interdependence among members. This is illustrated in Figure 4-29 below. This illustrates the complex interdependences that can exist for a given mission. Recall that these elements are typically from different services and coalition partners. In this case, the demands on the members

are quite high in terms of coordination of actions. We would expect different interaction patterns to emerge with different levels of interdependence. We believe it plausible that this could impact the effectiveness of net centric technologies and practices. Therefore, gathering information on the nature of the dependencies is important if we are to evaluate the impact of net-centric technologies and practices on outcomes.

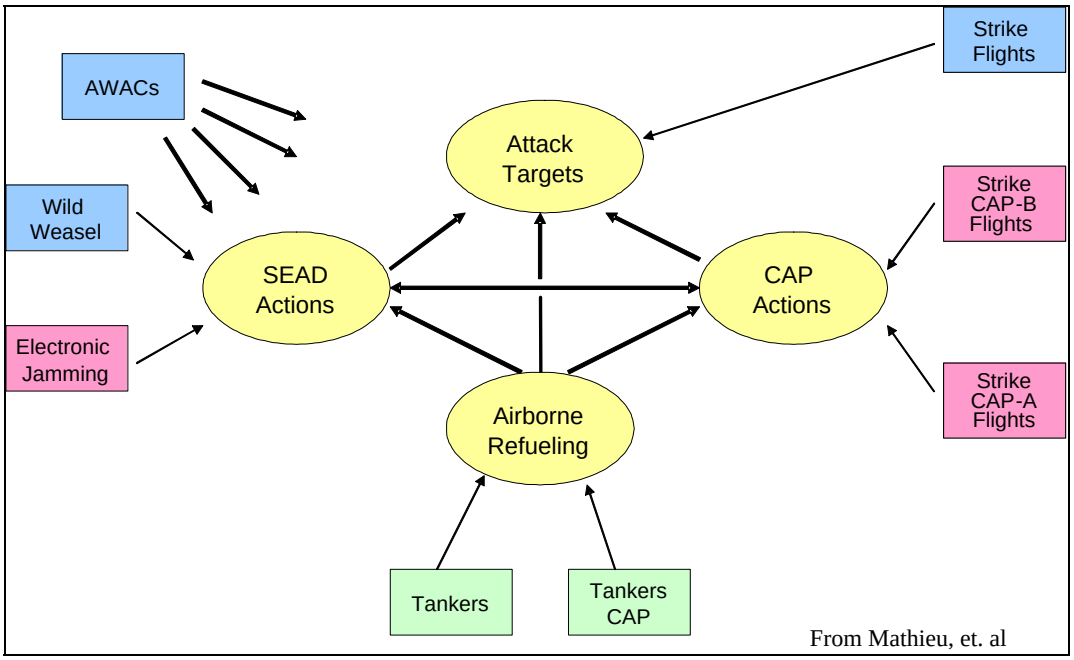


*Figure 4-29. Organizational Characteristics: Interdependence*

### *4.4.6 Organizational and Individual Behaviors*

Organizational and Individual Behaviors are processes that impact the quality of interactions. These include the level of cooperation, the efficiency of the interactions, how synchronized are the interactions, how engaged are the participants and the extent to which members spend their time and efforts on performing tasks versus maintaining the team (see Figure 4-30 below).

| Attributes | Definitions |
|---|---|
| Cooperation | Extent to which member(s) are willing and able to work together |
| Efficiency | Extent to which members utilize one another' s resources so as to minimize costs and maximize benefits |
| Synchronization | Extent to which organization is conflicted, deconflicted, or synergistic |
| Engagement | Extent to which all members actively and continuously participate |
| Team vs. Task Balance | Extent to which efforts are directed to organizational issues vs. relating to the objective |

*Figure 4-30. Exogenous Variables: Organizational and Individual Behaviors*

The attribute Engagement is useful to illustrate how it is an appropriate measure of quality of interactions. In the Air-to-Air case study, it was hypothesized that one explanation for the

increased kill ratio was the fact that the wingman could actively engage in attacks, rather than passively gathering, monitoring and reporting information.

Interactions involve force entities actively sharing information, and developing awareness, understanding and/or making decisions (developing plans) in a collaborative fashion while working together toward a common purpose. In the Conceptual Framework, Quality of Interactions bridges the gap between individual and shared information and sensemaking and cuts across the Information, Cognitive and Social Domains. It includes important "control variables" that impact performance and effectiveness, such as individual and organizational characteristics and behaviors. It is a crucial intermediate step between network centric technologies and outcomes. It is essential to have a way to measure the extent to which network centric processes are being implemented. The Quality of Interactions attributes and metrics provides this.

# 5.0 Summary

The NCO Conceptual Framework represents the latest innovations in the theory of Network Centric Operations. It builds on the original tenets of NCW and extends them in significant ways: Agility is introduced as a key concept of Network Centric Operations; the social domain is explicitly introduced; and the distinction between individual and shared sensemaking is highlighted. The NCO CF "top-level" extends and elaborates the key concepts of the tenets and develops those concepts that mediate between changes in network centric technologies and practices and mission effectiveness. It provides a means to capture evidence on the co-evolving elements of MCPs that result from changes in network centricity. The NCO CF presents a rich set of attributes and metrics for each top-level concept, providing the means for researchers and analysts to gather evidence on NCO related activities. This facilitates evaluation of progress toward NCO and, importantly, facilitates answering the key question "what is the impact of NCO on mission outcomes?" The NCO CF helps us to answer the "why" question, that is, it provides the means to explain the dramatic increases in effectiveness that are being reported when network centric technologies and practices are adopted. The Air-to-Air case study provides an important initial validation of the NCO CF. As the NCO CF is applied to more case studies and utilized in experiments and other applications, it is anticipated that it will continue to mature and develop; contributing to a growing knowledge base on NCO related data and evidence that can be used in the effort to transform the DoD.

The transformation of the DoD from an industrial to an information age organization is underway. The Office of Force Transformation is leading this effort, in part by conducting and sponsoring cutting edge research on transformation related technologies and practices. Network Centric Operations is a crucial element of transformation and is the focus of this document. The OFT's support of the Network Centric Operations Conceptual Framework Program is intended to mature the theory of network centric operations, refine and further develop the Conceptual Framework by applying it enterprise wide (experimentation, active engagements, case studies, and short courses). This document, the Draft Network Centric Operations Conceptual Framework Version 1.0, is intended to summarize the current version of the NCO Conceptual Framework. It is the draft version of the first of two formal versions of the Conceptual Framework expected. As the Conceptual Framework evolves over the course of the NCO CF Program, future versions of this document will capture those changes.